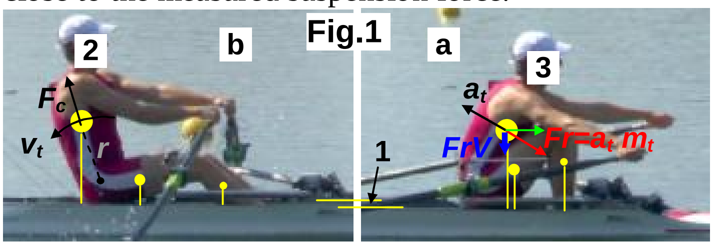
### *What causes rower's mass suspension?*

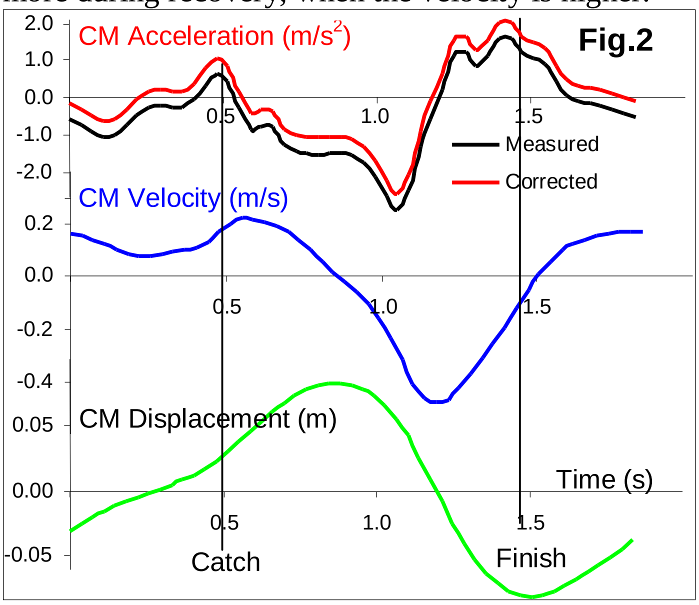
We have received interesting feedback on our findings about rower's suspension published in the previous Newsletter. Dr. Volker Nolte, a professor of Western Ontario university, Canada, noted that the only reason of suspension is the inertial force created by vertical acceleration $a_{CM}$ of rower's CM (centre of mass) $m_{CM}$. His version of the equation 1 from RBN 2013/08 is the following:

$$\Sigma_F = F_{FootV} + F_{seat} + F_{HandleV} - W = m_{CM}\, a_{CM} \qquad (1)$$

In this case, the average suspension force $\Sigma_F$ over the stroke cycle must be zero, because the average vertical acceleration of rower's CM must be zero. However, in our measurement the average suspension force was 43N in that data sample. If it explained only by acceleration of the rower's CM, then its position would be about 1m lower after each stroke cycle, i.e. 100m below water level after 100 strokes, which is not possible. Another obvious evidence of existence of the suspension can be seen with naked eye: the boat if lifted up by 3-4 cm during the drive (Fig.1, 1), which corresponds to 15-20kg lighter rower's weight and close to the measured suspension force.




Volker's counter-arguments were the following: 1. The offset of the average suspension force could be explained by error in the measurements. 2. The visible vertical movements of the hull could be explained by water-forces: it sinks into the water since the water has a velocity relative to the hull and the pressure lowers, more during recovery, when the velocity is higher.




To check Volker's hypothesis, we have added an offset to the measured suspension force to make average acceleration of rower's CM over the stroke cycle equal to zero (Fig.2). However, the derived displacement of the rower's CM looks very strange: its position at the middle of the drive ~12cm higher than at the middle of recovery, which makes this hypothesis quite unlikely.

Another interesting hypothesis came from a master's rower and an engineer Tor Anderson of Los Gatos Rowing Club, CA, US: "It looks like peaks in suspension force occur when the body swings, both on the drive (7, Fig.2, RBN 2013/08) as well as the recovery (2). It seems one of the contributions to these peaks is centripetal force $F_c$ of the body swing, acting in the vertical direction:"

$$F_c = m_t\, v_t^2 / r \qquad (2)$$

where $m_t$ – mass-moment of the trunk with head, $v_t$ – its instantaneous linear velocity, r - radius of inertia from the centre at hips joint (Fig.1, 2). Plugging the data $m_t$ = 25kg, $v_t$ = 1.25 m/s, and $r$ = 0.4 m (roughly 50% of the height of the torso with head), we got a force of ~100N in the vertical direction, which is close to the magnitude of the bump 7 during the drive.

However, it was decided that the centripetal force can not be the reason for the fact that the average suspension force over the stroke cycle is higher than zero. Upwards centripetal force should be balanced by downwards the reaction force $FrV$ (Fig.1, 3) caused by the trunk acceleration at the catch and finish.

So, **the mechanics of the suspension force is still not completely clear** to us. More experiments and analysis needed.

### *Normative data in rowers' groups*

Statistical analysis was conducted on the data obtained in various levels of rowers in our standard test (RBN 2013/03). Five rower's groups were defined:

1. **Beginners** – rowers with little experience of qualified coaching;
2. **Students** of universities and colleges aged 17-21;
3. **National** level rowers of various ages – not members of national teams;
4. **International** level rowers
5. **Champions** – medallists of Olympics and Worlds.

The deviations from the target values for each rowers' category (male/female, sweep/sculling, LW/HW, RBN 2009/05) were obtained and averaged in the rower's levels. Table 1 shows how much the main mechanical variables (stroke length and average force) LOWER than targets:

| Table 1 | n | Length | Force |
|---|---|---|---|
| Beginners | 53 | >8% | >30% |
| Students | 245 | 5-8% | 20-30% |
| National | 222 | 3-5% | 12-20% |
| International | 162 | 1-3% | 5-12% |
| Champions | 15 | <1% | <5% |

The table could be used for evaluation of results of biomechanical testing.