THE EFFECTS OF STROKE RATE ON BIOMECHANICAL PARAMETERS AND EFFICIENCY OF ROWING.

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INTRODUCTION

While a lot of works on rowing biomechanics was done, only a few of them studied dependence of motions' structure on the stroke rate. So this problem was studied by Martin and Bernfield (1980). Olympic rowing eight crew was filmed at stroke rates of 37, 39 and 41 strokes per minute in order that the effect of stroke rate changes on the velocity of a rowing shell could be examined. A significant positive relationship was found between stroke rate and average velocity. Analysis of the phases of the stroke cycle determined that increased boat velocity was accomplished by a greater application of force during the drive phase and the exertion of force over a greater percentage of the time for the stroke cycle.

The problem was not fully solved because of limited number of experimental data, narrow interval of stroke rate and absence of direct registraton of applied forces.

The purpose of the study was to determine in more details how biomechanical parameters and mechanical efficiency of rowing depend on stroke rate.

METHODS

There was used the computerized rowing simulator "IGL-1" (Kleshnev V.V. et al., 1995), which provide the maximum similarity to real boat rowing motions. The simulator was equipped with gauges of mechanical parameters, analog-to-digital converter (12 bit, 16 channels, 50 hertz) and personal computer.

A group of elite oarsmen (n = 27, 1.94±0.07 m, 92.7±8.9 kg, 23.0±3.8 yr., X±SD) performed three test trials on "IGL-1" (**T1**, **T2** and **T3**). The duration of each trial was one minute. The athletes were instructed to maintain the training stroke rate in the first trial, racing rate in the second one and submaximal rate in the third one.

The measured data were processed using developed algorithm and patterns of primary and derivative mechanical parameters were produced. The patterns gave an oppotunity to compare qualitative structure of rowing at the different stroke rate. Quantitative criteria of the patterns were used for determination of stroke rate effect on rowing structure.

RESULTS

An average stroke rate was 26.0±3.2, 32.0±2.4 and 36.5±2.7 strokes per minute in each trial respectively.

In the group of time criteria strong relationship was determined between stroke rate and rowing rhythm that we define as part time of drive phase time in total cycle time. The correlation factor was $r=0.85$ ($p<0.001$), and regression equation was $y=0.84x+25.1$.

The handle force increased with stroke rate increasing (figure a). Maximal handle force significantly increased ($r=0.62$, $p<0.001$, $y=0.16x+4.59$), but it's gradient at beginning of the drive was not increased, that caused longer time of peak handle force achieving (r=0.41, p<0.01, y=0.35x+13.9) and lower average-to-maximal ratio.

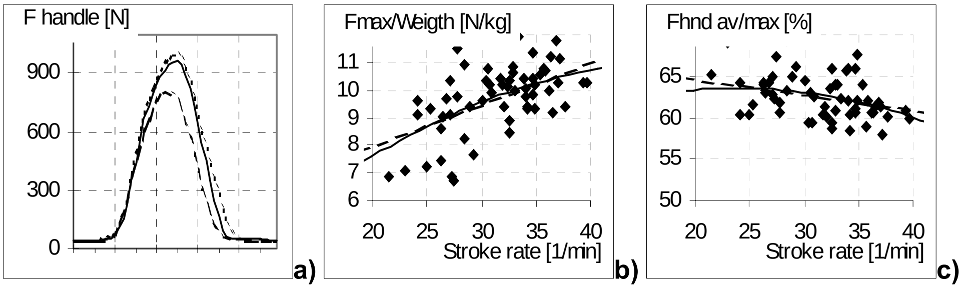

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Figure A. Patterns of the handle force (a) at different stroke rate, trends of dependences of maximal handle force (b) and it's average-to-maximal ratio (c) on stroke rate.

Power of rowing (figure b) also significantly increased when the stroke rate increasing (r=0.84, p<0.01, y=0.20x-1.35), but it's time structure was not changed. Parts of legs and trunk in total rowing power practically was not changed (r=0.25, p>0.05 and r=0.27, p>0.05 respectively), but part of arms power (figure b, c) significantly decreased (r=-0.60, p<0.01, y=-0.57x+39.1).

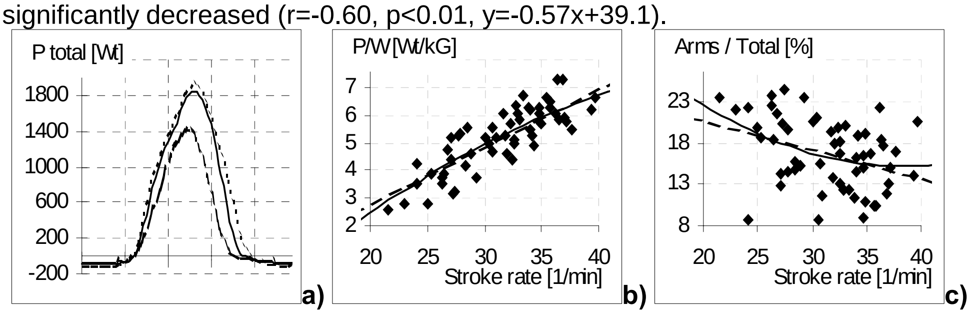

Figure B. Patterns of the instant power on the handle (a), trends of dependences of relative rowing power on stroke rate (b) and part of arms power (c).

Patterns of the segments instant power during stroke cycle had various dinamics at different stroke rate (figure c).

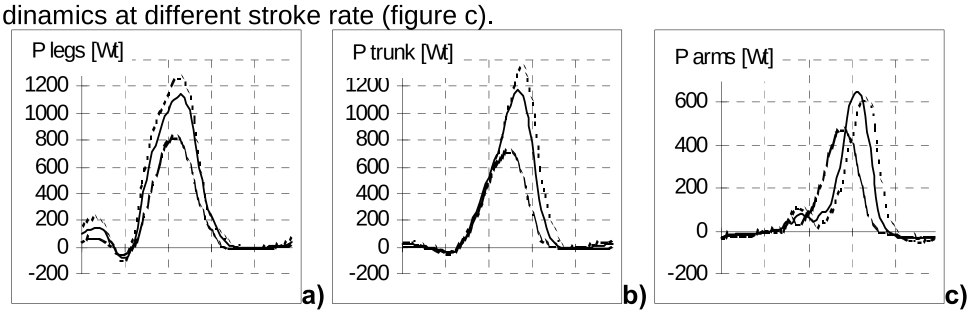

Figure C. Patterns of the instant powers of legs (a), trunk (b) and arms (c) at different stroke rate.

Power of the legs proportionally increased when the stroke rate increasing. Power of the trunk also increased, but it's gradient was the same and peak was shifted towards drive end. The curve of arms' power was significantly shifted towards drive end (r=0.49, p<0.05, y=0.42x+63.12) and had changed shape.

There were also determined correlations between the stroke rate and average velocities of the handle (r=0.78, p<0.001, y=0.026x+0.75), the legs (r=0.53, p<0.01, y=0.013x+0.17), the trunk (r=0.56, p<0.01, y=0.015x+0.17) and the arms (r=0.57, p<0.01, y=0.025x+0.082),

Construction of the rowing "IGL-1" allow to calculate velocity of the boat shell, that correspond to the value of instant drag force applied to the mobile workplace of the simulator (figure d). Results of analisys of this valocity showed that it's average value had strong positive correlation with the stroke rate (r=0.79, p<0.001, y=0.06x+1.82). Variation of boat velocity during stroke cycle decreased when the stroke rate increasing (r=-0.59, p<0.01, y=-0.17x+14.8).

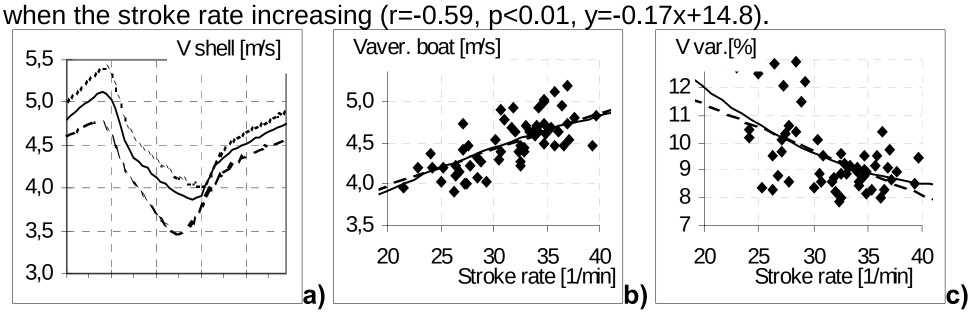

Figure D. Patterns of the calculated boat velocity (a), trends of dependences of average boat velocity (b) and relative fluctuation of boat velocity (c) on stroke rate.

When the stroke rate increasing the dynamics of acceleration of the "shell" during stroke cycle changed significantly (figure e, a). At drive beginning the negative peaks of this parameter became lower and at the end of the drive it's positive peaks became higher.

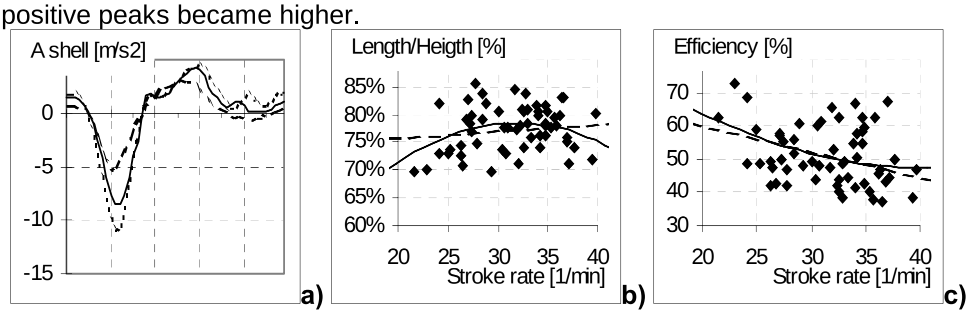

Figure E. Patterns of the shell acceleration (a), trends of dependences of the stroke length (b) and rowing mechanical efficiency (c) on stroke rate.

Correlation between the stroke rate and the stroke length had not statistically reliable value (r = 0.14, p>0.05, determination factor R^2=0.021). But when nonlinear dependence of this values considering (figure e, b) higher determination factor was founded (R^2=0.19, p<0.05, y=-0.001x^2+0.032x+0.27).

The mechanical efficiency of rowing was determined as a ratio of the energy dissipated by drag force to the energy applied by the rower (figure e, c). This criterion had negative correlation with the stroke rate (r=-0.51, p<0.01, y=-0.88x+77.4). The nonlinear analysis indicate that the mechanical efficiency decreases until the rate of 38-40 strokes per minute and then became stable ($y=0.037x^2-3.05x+109.5$, $R^2=0.19$).

CONCLUSION

Results of the study are in accordance with findings of previous researchers that the stroke rate has got significant positive correlations with average velocity, force application and part time of drive phase in elite oarsmen.

Correlation between stroke rate and longitudinal criteria of rowing has nonlinear character and the highest values of the stroke length could be expected at the rate from 30 to 35 strokes per minute.

The study also defines that stroke rate strong correlate with rowing power and change structure of body segments' power by means of decreasing of part of arms power.

The most unexpected finding of the study was that stroke rate has negative correlation both with the boat velocity variation and the mechanical efficiency of rowing. A number of previous researches indicated that the boat velocity variation is the main reason of decreasing rowing efficiency (for instance Millward A., 1987). But in this study the boat velocity variation and the mechanical efficiency of rowing decreased together when the stroke rate increasing.

Obviously, it exists another mechanism of energy wasting at high stroke rate, which increases power dissipating more significantly, than it saved by means of decreased velocity variation. The reasons of this fenomena should be the subject of the following investigations.

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