EFFECT OF STROKE RATE ON MECHANICAL POWER FLOW IN ROWING

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INTRODUCTION

In competitive rowing, a large amount of mechanical power is produced. However, only the fraction of power that contributes to average velocity will determine the performance. In this study the previously established power equation of rowing [1] is used to analyze rowing performance. Mechanical power is lost by moving water with the blades. Power is lost to water friction on the hull which is related to velocity cubed. Those power losses are higher when there are larger fluctuations in velocity. Due to the intermittency of propulsion, and due to impulse exchange between the rower and the hull, these fluctuations are substantial. Stroke rate is an important aspect of rowing technique. In this study the effect of stroke rate on the power flow in rowing was investigated.

METHODS

Nine subjects participated in this study. Subjects were instructed to row a minimum of 10 consistant strokes at rates of 20, 24, 28, 32 and 36 strokes per minute with maximal intensity. Subjects rowed 5 trials at each prescribed stroke rate.

Forces on the pin were measured using piezoelectric transducers (Kistler, Switzerland). Oar angle in the horizontal plane was measured using servo-potentiometers (Radiospares). Boat velocity was measured using a trailing turbine with embedded magnets (Nielsen Kellermann). Data was transmitted to the shore using telemetry (ROWSYS, Australia).

Steady state rowing was assumed to be perfectly periodic. In this situation, the average power production during the stroke cycle ($\bar{P}_{rower}$) equals the average power losses to drag ($\bar{P}_{drag}$) and moving water with the blades ($\bar{P}_{blade}$).

Propelling efficiency ($e_{propelling}$) was calculated as the fraction of $\bar{P}_{rower}$ *not* lost to the blades. Velocity efficiency ($e_{velocity}$) was calculated as the fraction of $\bar{P}_{rower}$ *not* lost to velocity fluctuations. From these two terms, the fraction of $\bar{P}_{rower}$ contributing to average velocity ($\bar{v}_{boat}$), defined as total efficiency (e_{total}) was calculated.

A repeated measures ANOVA was used to analyze the data. Pearson's correlation coefficient was also calculated.

RESULTS AND DISCUSSION

A significant main effect of stroke rate was found for $\bar{P}_{rower}$, $e_{propelling}$, $e_{velocity}$, e_{total} and $\bar{v}_{boat}$ (all $p<0.0001$). The correlation of these variables with stroke rate were 0.98, 0.82, -0.72, 0.73 and 0.96 respectively, indicating strong linear relationships (correlation coefficients are averaged over subjects). In table 1 the mean values are presented.

The increase of velocity at higher stroke rates was mainly caused by the increase in $\bar{P}_{rower}$. However, rowers are probably not able to maintain the values found for $\bar{P}_{rower}$ throughout a typical 2000m rowing race.

The decrease of $e_{velocity}$ at increasing stroke rate was expected and is caused by a higher $\bar{v}_{boat}$ and larger accelerations and decelerations by the rower itself. However, e_{total} increases at increasing stroke rate, caused by a substantial increase of $e_{propelling}$. While the mechanical work of the rower remains relatively constant with increasing stroke rate, the energy lost at the blades actually *decreases*. This is most likely related to the finding that at higher stroke rate the blade travels less in the direction opposite the propulsion, thus less water is being moved.

CONCLUSIONS

This study shows the power equation to be an adequate conceptual model to analyze rowing performance. Results indicate that stroke rate not only affects the power output of the rower, but also affects the power loss at the blades and the power loss associated with velocity fluctuations. When similar results become available regarding the effect of other technique-related factors, it may become possible to understand the optimal technique as the optimal compromise between generation of power by the rower and power loss to terms not contributing to average velocity.

REFERENCES

1. Ingen Schenau G.J.v., Cavanagh P.R. *Journal of Biomechanics* **23 (9)**, 865-881 (1990).

Table 1: Average values and standard deviations (between parentheses) for the stroke rates investigated.

Stroke rate	$\bar{v}_{boat}$ (m/s)	$\bar{P}_{rower}$ (W)	$e_{propelling}$	$e_{velocity}$	e_{total}
20	3.84 (0.32)	277 (74.0)	0.785 (0.019)	0.955 (0.0062)	0.740 (0.021)
24	4.07 (0.29)	328 (77.6)	0.797 (0.019)	0.954 (0.0068)	0.751 (0.022)
28	4.33 (0.37)	389 (95.8)	0.812 (0.019)	0.953 (0.0070)	0.765 (0.020)
32	4.52 (0.30)	441 (98.1)	0.821 (0.019)	0.950 (0.0067)	0.770 (0.021)
36	4.76 (0.76)	505 (118)	0.830 (0.017)	0.947 (0.0074)	0.777 (0.019)