ERGOMETER ROWING PERFORMANCE IMPROVES OVER 2000 M WHEN USING A STEEPER FOOT-STRETCHER ANGLE

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The effect of changing foot-stretcher angle on a rowers' mechanics, power output and 2000 m race ergometer performance time were examined. Eight male and seven female national rowers completed a 2000 m rowing race on three consecutive days with the foot-stretcher angle set to 36°, 41° (currently used angle) or 46°. The Concept II ergometer was instrumented to measure normal force under the feet, handle force and seat position. Concept II ergometer power output improved when the foot-stretcher angle was increased from 36° to 46°. The magnitude of the effect was related to gender as at 46° the mean improvement for experienced males was 2.4% and for experienced females was 0.8%.

KEY WORDS: rowing, performance, foot-stretcher angle, Concept II

INTRODUCTION: When rowing, the foot-stretcher provides a solid base against which the rower can apply force to produce forward propulsion of the boat. By placing the foot stretcher in a more vertical position (increased angle) a greater proportion of the total applied force is directed in line with the boat. Rowers currently set the foot-stretcher for comfort rather than mechanical merit. The purpose of the current study was to gain a better understanding of the effect of foot-stretcher angle on a rowers' mechanics and ultimately their 2000 m race performance. Potential covariates such as foot position at catch and ankle joint range of motion were considered.

METHODS: Eight male and seven female national rowers (n=15) participated in the study. Following a familiarisation session each rower completed a 2000 m rowing race on three consecutive days with the foot-stretcher angle set to 36°, 41° or 46°. The foot-stretcher angles where chosen as they were representative of the currently used angle (41°) and two practical variations either side (36° and 46°) that theoretically may influence force application profiles. Performance measures of mean power output and race time were recorded. The Concept II ergometer was instrumented to measure normal force under the feet, handle force and seat position. Data were collected (100 Hz) and analysed using custom designed LabVIEW programmes. Additionally, reflective bone markers attached to the rower's right side were videoed. Automatic digitising using APAS software at 50 Hz provided joint kinematics. All data were synchronised using a 5 V pulse and LCD light.

Statistical analysis: Differences in scores for each variable between the current foot-stretcher angle (41°) and experimental foot-stretcher angles (36° and 46°) were calculated. The effect of foot-stretcher angle was determined with repeated measures analysis using Prox Mixed in the Statistical Analysis System (Version 8.2, SAS Institute, Cary, NC). To account for a learning effect, the order of treatment was included as a within-subject effect. Precision of estimates of outcome statistics is shown as the 95% CL, which defines the likely range of the true value in the population.

RESULTS: Figure 1 shows the changes in total race time and mean power output at three foot-stretcher angles for the female and male rowers. The male rowers were faster over 2000 m (14.7%, 90% CL, 12.2 – 17.1), produced more power (61%, 90% CL, 47.7 – 75.5), had lower heart rates (4.8%, 90% CL, 2.3 – 11.9) and rated their perceived exertion lower (1.1%, 90% CL, 0.5 – 1.6) than the female rowers. As the foot-stretcher angle increased from 36° to 46° mean power output over 2000-m increased (p = 0.00) for the male rowers by 2.4% (90% CL: 1.6 – 3.3) and consequently race time decreased (p = 0.00) by 0.8% (90% CL: 0.5 – 1.1). Although a similar pattern was observed for the female rowers, the wide confidence limits indicated considerable uncertainty. As the foot-stretcher angle got steeper, total applied handle force and normal foot-stretcher force tended to increase for both the male and female rowers. The most common strategy used to cope with any given foot-stretcher angle was to manipulate the heel position with respect to the toes. The foot position was manipulated in order to retain the similar knee, hip and trunk angular positions across all foot-stretcher angles. No changes in angular velocities were observed. Individual rowers' responses to the change in foot-stretcher angle do not appear to be explained by a rower's foot position at the catch or their ankle flexibility.

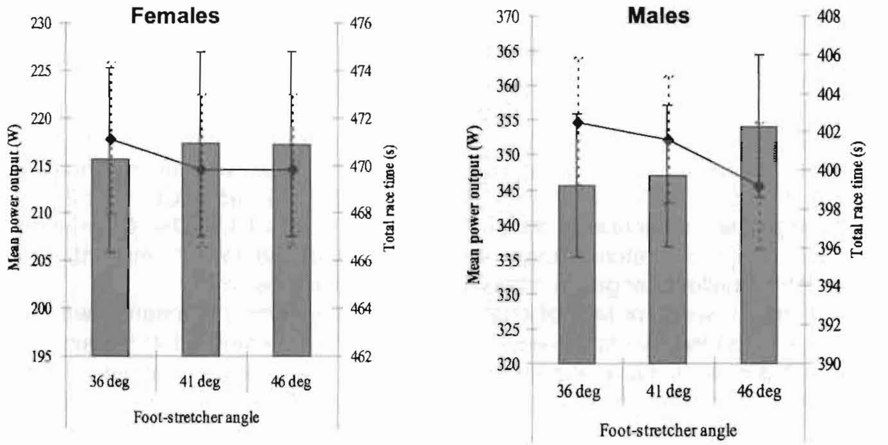

Figure 1 Changes in total race time ± SD (line,♦) and mean power output ± SD (bar) at three foot-stretcher angles for the female (n = 7) and male (n = 8) rowers (the dashed SD are associated with total race time).

Male rowers	Female rowers
Ergometer rowing performance	
▪ 0.8% ⇓ Total race time	
▪ 2.4% ⇑ Total mean power	
▪ 4.2% ⇑ 3rd quarter mean power	
Ergometer rowing kinetics	
▪ 22.7% ⇑ Peak-F_{N-x}	12.0% ⇑ Peak-F_{N-x} ▪
▪ 13.9% ⇓ Peak-F_{N-y}	21.4% ⇓ Peak-F_{N-y} ▪
▪ 30.5% ⇑ Time to Peak-F_N	21.1% ⇑ Time to Peak-F_N ▪
	7.7% ⇓ Peak-F_N ▪
Ergometer rowing kinematics	
▪ 2.8 cm ⇑ Max $Seat_{DIS}$	2.6 cm ⇑ Max $Seat_{DIS}$ ▪
▪ 3.0 cm ⇑ Mean $Seat_{DIS}$ at Peak-F_N	1.9 cm ⇑ Total $Seat_{DIS}$ ▪
▪ 2.1 cm ⇑ Min $Handle_{DIS}$	2.4 cm ⇑ Mean $Seat_{DIS}$ at Peak-F_N ▪
▪ 3.9° ⇓ Ankle angle at catch	
▪ 0.8° ⇓ Trunk angle at catch	
▪ 3.5° ⇑ Foot angle at catch	

Figure 2 Summary of significant performance and biomechanical change scores seen for the male and female rowers when the foot-stretcher angle was increased from 36° to 46°.

Figure 2 provides a summary of the significant changes in performance, kinetics and kinematics when the foot-stretcher angle was increased from 36° to 46° for the male and female rowers.

DISCUSSION AND IMPLICATIONS: The greater stroke rate and reduced oar excursion used by the male rowers when the foot-stretcher angle was changed from 36° to 46° during the 2000 m ergometer trials supports previously published correlations that have illustrated the positive relationship between stroke rate and oar excursion (r = -0.99) (McBride, 1998). The current finding supports previously unpublished research by the authors investigating the effects of foot-stretcher angle during on-water sculling (Soper & Hume, 2004a) and on the RowPerfect ergometer (Soper & Hume, 2003), which showed decreases in handle excursion as the foot-stretcher angle got steeper.

The uncertainty surrounding the improvements in performance of the female rowers with increasing foot-stretcher angle is indicated by the wide 95% CL. The variability in the females' individual response to the change in foot-stretcher angle was nearly three times (2.8%, 95% CL = -2.5 – 4.7) that of the male rowers (-1.0%, 95% CL = -2.2 – 1.7). Additionally, the significantly decreased stroke rate (0.6 spm, 95% CL -1.0 – -0.1) during the 2000 m trials with the foot-stretcher angle set to 46° compared to 36°, may have been associated with their smaller changes in mean power and total race time.

The changes for male rowers, or lack of changes for female rowers, in mean power output and total race time when the foot-stretcher angle varied from the standard 41° position were not associated with a rower's maximal passive dorsiflexion. The positive association of mean power output/total race time with tibia and leg (tibia plus femur) length supports previous data (Bourgois et al., 2001) that show female rowing finalists have significantly longer legs than non-finalists. However, changes in foot-stretcher angle did not appear to strengthen or weaken this association. The female rowers' produced less mean power output and had shorter legs than their male counterparts, suggesting the tibial or leg length was not causal in the apparent gender effect of foot-stretcher angle on performance.

Seat displacement ($Seat_{DIS}$) is minimum when the rowers are in the catch position preparing for the drive phase of the stroke cycle and maximum at the finish position when the legs are extended. As expected Max-$Seat_{DIS}$ and $Seat_{DIS}$ at Peak-F_N increased significantly when the foot-stretcher angle was set to 46° for the male and female rowers, and would primarily be due to the displacement of the foot-stretcher and rower backwards on the rail at the steeper foot-stretcher angle.

The time between start of seat movement (initiation of the drive phase) and start of F_H handle force (s) is indicative of the initiation of propulsive force application to the foot-stretcher (McBride & Elliott, 1999). $Seat_{DIS}$ was initiated on average 0.12 – 0.14 s prior to the initiation of F_H. Zatsiorsky and Yakunin (1991) cited German and Russian research that reported foot-stretcher force application initiated 0.15-0.22 s prior to the blade entering the water during on-water rowing. Early foot force application (also indicated by the initiation of seat movement down the slide) will transfer negative propulsive forces to the foot-stretcher and skiff. Therefore, the timing of leg drive at the catch and the application handle/oar force is important (McBride & Elliott, 1999). In the current research there was no effect of foot-stretcher angle on the magnitude of the time delay between the initiation of $Seat_{DIS}$ and F_H.

It is unclear why the male rowers benefited more from a steeper foot-stretcher angle than the female rowers. Passive maximal dorsiflexion angle achieved by the male and female rowers did not explain the gender difference. It is proposed that a higher resultant force on the foot-stretcher will occur due to increased normal force and decreased shear force. The applicability of the current findings to on-water research is unclear.

CONCLUSION: Concept II ergometer power output improves when the foot-stretcher angle is increased from 36° to 46°. The magnitude of the effect does however appear to be related to gender as at 46° the mean improvement for experienced males was 2.4% and for experienced females was 0.8%.

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