A SIMPLE 1^+ DIMENSIONAL MODEL OF ROWING MIMICS OBSERVED FORCES AND MOTIONS

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INTRODUCTION

The first attempt to make a reasonable mechanical analysis of sliding-seat “sweep” rowing was presumably that of Alexander (1925). He neglected vertical motions of the centers of mass of the rower and boat as well as the yawing and pitching motions of the boat. He assumed one dimensional mechanics (momentum balance in the fore-aft direction), a point mass rower, an infinitely stiff oar, and quadratic force-velocity relationships to model drag forces on the boat and oar blade. He did take account of the 2D (looking down) kinematics and forces of the oar. Alexander prescribed made-up velocity vs. time patterns for the rower’s legs, back, and arms to predict, using numerical integration (1925!), the motions of the system. Comparison with the scant data available was somewhat favorable. Pope (1973) used a similar but less complete model that had less good agreement with physical measurements.

Recent models (e.g. Brearley and de Mestre (1996) and Lazauskas (1997)) reasonably predict Olympic race times at the expense of producing or assuming force profiles which differ in many respects from on-water data. Atkinson (2001) uses a model in the same spirit, but with several extra kinematic variables, and gets better agreement with observed measurements.

METHODS

Our model is the same as Alexander's with some minor elaborations that are allowed by our access to faster computation (Fig 1). We can use more general drag laws on the oar and boat. The length vs. time curves of the various body parts (*the coordination strategy*) are somewhat arbitrary. The oar goes in and out of the water so that it generates thrust while in the water and stays out when it would backsplash.

For a given coordination strategy, person, and boat parameters, we use shooting to find periodic solutions.

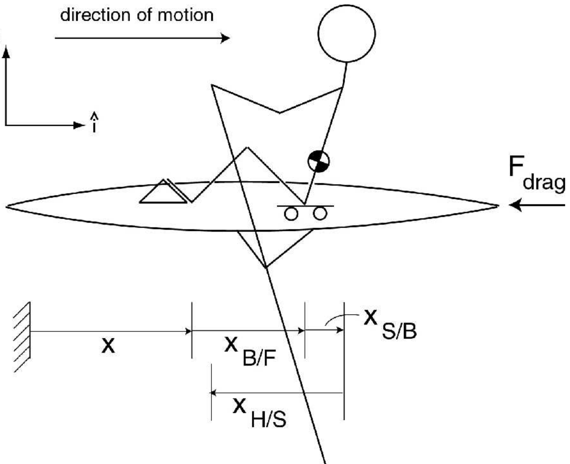

Figure 1: A sketch of the boat-oar-rower system is shown (top view of boat and oar, side view of rower). The various x' s are the

controlled and measured kinematic variables.

RESULTS AND DISCUSSION

Using numerical optimization on the coordination strategy, also allowing variation of some of the drag and rigging constants, we attempted to match some kinematic and force data from rowing (Fig 2). Note the presence of zero force during the recovery in our model. This is due to the assumption of a massless oar. The work rate of one rower was about 502 watts. The total negative work of all body parts was (a small) 5% of the total work thus supporting the claim that the leg-back-arms rowing coordination strategy is constructed so as to minimize negative work (the positive work of the arms at the end of the drive eliminates the need for negative work to stop the relative motion of the boat and body).

We also checked the possibility of improving our model by adding oar mass flexibility and got only small improvements. On the other hand neglecting oar slip seems significant.

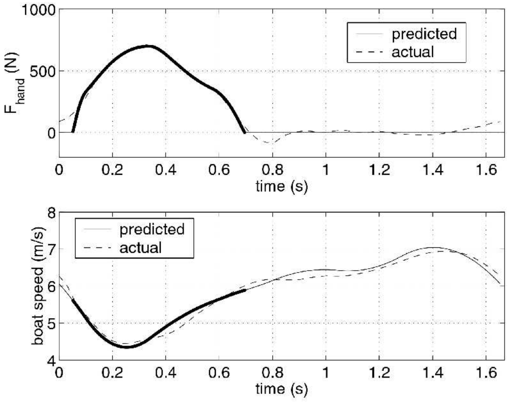

Figure 2: This plot shows a comparison of our model results (solid) with data from Kleshnev (dashed). The bold portions of the predicted curves indicate the drive sequence.

SUMMARY

We have constructed a model of rowing that seems to have the minimal complexity to well model the sport. The model seems promising for the investigation of the following questions: What kind of performance optimization will recreate observed rowing patterns? How can rigging be adjusted for various strength and height rowers to row together optimally? Can a moving coxswain make a boat go faster? What aspects of the coordination strategy are most central for maximizing performance?

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