DETERMINATION OF THE OPTIMAL SEAT POSITION THAT MAXIMIZES AVERAGE CRANK POWER: A THEORETICAL STUDY

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INTRODUCTION

As competitive cycling becomes more popular, there is increased demand to develop new methods to improve performance. One method is to alter the bicycle-rider geometry to change the lower extremity kinematics and take advantage of muscle force-length-velocity relationships to increase power output. A common way to change the geometry is to modify the seat position relative to the crank center. Indeed, there are differences in preferred seat position even among racing disciplines (e.g., road racers vs triathletes). Although altering different aspects of seat position (e.g. Nordeen-Snyder, 1977) on cycling performance have been investigated, there has been no study that has systematically assessed the sensitivity of crank power to a wide range of seat positions. The purpose of this study was to use modeling and simulation techniques to determine the optimal seat position that maximizes average crank power while pedaling at 90 rpm.

METHODS AND PROCEDURES

A detailed musculoskeletal model (Neptune and Hull, 1998) with 15 individual muscle actuators per leg and forward dynamic simulations were used with dynamic optimization to determine the optimal seat position that maximizes average crank power during isokinetic pedaling at 90 rpm. Two sets of optimizations were performed. First, the muscle excitation patterns and seat position (i.e. location and seat orientation) that maximized crank power over a single revolution were determined. The seat was allowed to vary ± 35 cm in the fore/aft and ± 40 cm in the vertical directions relative to the crank center. These variations in seat position essentially altered the seat tube angle and seat height. Second, optimal excitation patterns and crank power were optimized over a wide range of seat tube angles relative to the solution obtained in the first optimization to assess the sensitivity of crank power to seat tube angle. In the model, the muscle actuators were governed by Hill-type muscle properties including the force-length-velocity relationships. Activation-deactivation dynamics were modeled with a first-order differential equation (Raasch et al., 1997) using activation and deactivation time constants of 20 and 30ms, respectively.

Following each optimization, the location of the seat relative to the crank center and the seat height (i.e. distance along the seat tube angle) were determined. Seat orientation was calculated as the angle between the seat's vertical axis and the seat tube angle (0^o angle corresponds to a seat perpendicular to the seat tube) and provides an indication of pelvis tilt since the pelvis is fixed to the seat in the model. In addition, average crank power and the range of motion (ROM) and mean values for the hip, knee, ankle, and pedal angles were determined to assess how the different seat positions influenced joint kinematics.

RESULTS

Interestingly, the maximum crank power varied little (within 6.4 watts) over a wide range of seat positions with a maximal value of 976.8 W (Fig. 1). The optimal solutions had a consistent seat height and orientation, with average (SD) values of 0.8041 (0.0014) m and -13.65(-0.45) degrees, respectively. Joint ROM and means for the hip, knee and ankle were consistent among all the optimal solutions with the largest variation occurring in the hip angle ROM (Table 1). Mean pedal angle varied greatly among the solutions (Table 1), but rotated clockwise in a systematic fashion as the seat moved forward.

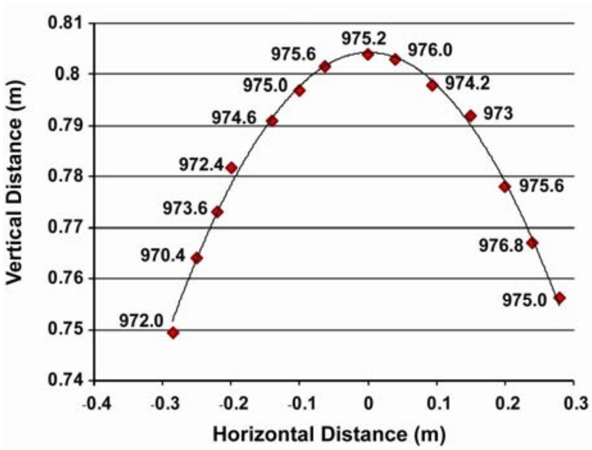

Figure 1. Location of optimal solutions (relative to crank center) and corresponding crank power output (W).

Angle	Mean° (SD)	ROM° (SD)
Hip	54.35 (0.56)	54.74 (0.36)
Knee	-78.27 (0.26)	94.06 (0.51)
Ankle	11.85 (0.37)	32.64 (0.42)
Pedal	-25.7 (13.63)	44.59 (0.52)

Table 1. Mean angle and ROM values for the pedal and lower extremity joint angles across optimal solutions. SD = standard deviation.

DISCUSSION

Maximum power was consistent across the optimal solutions, with differences within 1% of the highest power output. Maximal power was obtained within a small range of seat heights and orientations. However, the seat tube angle did not affect power output.

Previous studies have shown that seat height alters joint kinematics during cycling (e.g. Nordeen-Snyder, 1977). Therefore, the narrow range for optimal seat height suggests that specific knee and ankle angles are optimal for producing power. Additionally, the small variation in these angles, regardless of seat tube angle, were consistent with the findings of Heil et al. (1997) who showed there is little variation in these angles over a range of seat tube angles at a given seat height. The consistent seat height and orientation across the optimal solutions also produced a constant hip angle (Table 1). Previous studies have shown that extreme hip angle values increase $\dot{V}O_2$ output during sub-maximal cycling (e.g. Heil et al., 1997). A possible explanation for these findings and for the consistent optimal seat orientation in the present study is that altered hip kinematics cause muscles crossing the hip joint to operate on non-optimal regions of the force-length curve, and therefore increase metabolic cost.

While pedal ROM was nearly constant among solutions, the average pedal angle systematically changed (rotated clockwise) as the seat moved forward, which allowed the joint kinematics to remain constant and near optimal for producing power (Table 1). This was consistent with Browning et al (1992) who showed pedal rotation was directly related to seat position in competitive cyclists.

CONCLUSIONS

There is an optimal seat height and orientation that maximizes crank power, but the maximum power is relatively independent of seat tube angle. Instead, the pedal angle is used to adjust the joint kinematics such that the joint angles remain within their optimal range that allows muscles to operate in a more favorable region of the force-length relationship and produce maximum power.

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