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The Effect of Seat-To-Pedal Distance on Anaerobic Power and Capacity in Recumbent Cycling

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INTRODUCTION

In 1933, Francois Faure defeated the world champion racing cyclist, Lemoire, in a 4-km pursuit race (Whitt & Wilson, 1982). What was unique about this feat, was that : (1) Faure was a relatively unknown cyclist; (2) he used a non-conventional bicycle (a recumbent bicycle); and (3) he broke previous track records established by conventional ones. In 1980, the single rider Vector tricycle established a new human powered speed record at 56.66 mph (91.22 km/hr) with the cyclist seated in a supine recumbent position. In 1992, the official human powered land-speed record has been set at 68.73 mph (110.65 km/hr) by a single rider in a recumbent bicycle named the Cheetah (Wilson, 1992). This would definitely suggest that recumbent bicycles are faster and more effective in establishing human powered land-speed records than conventional bicycles.

It is well documented that non-conventional human powered vehicles are more effective aerodynamically than the standard racing bicycle (Kyle 1974, 1982; Kyle & Caiozzo, 1986; Kyle, Crawford, & Nadeau, 1973, 1974; Whitt & Wilson, 1982). With speeds of human powered vehicles exceeding 60 mph (96.6 km/hr) (Gross, Kyle, & Malewicki, 1983), it is obvious as to the importance of minimizing aerodynamic drag. But when the drag coefficient and effective frontal area have been reduced to 0.11 and 0.5 square feet, respectively, as in the Vector Single (compared to 1.1 and 6.0 square feet, respectively, for a standard upright bicycle) (Gross et al., 1983), it is questionable as to (1) how much lower the aerodynamic drag can be reduced; and (2) how significant such changes would be.

To further improve performance in human powered vehicles, it becomes essential to focus on some aspect other than the aerodynamic variables. The most logical area for investigation would be the human "engine" which power the vehicle (i.e., the man-machine interface). How does the human organism interact with human powered vehicles to maximize performance? What is the most effective body position, body orientation, body configuration, seat-to-pedal distance, and pedal crank-arm length that would maximize power production in cycling?

It has been determined that the body position (bicycle seat-tube angle) which maximize

power production in cycling is 75 degrees, with a mean hip angle of approximately 75

degrees and the trunk perpendicular to the ground (Too. 1991b). Another investigation

(Too, in press, 1991a), using the same 75 degree seat-tube angle, and comparing the effect

of a systematic manipulation in trunk orientation with respect to the ground, reported power

output to be significantly greater in an upright orientation than in a semi-supine orientation.

To continue along this line of research in determining the most effective cycling

position, the purpose of this investigation was to determine the effect of systematic changes

in seat-to-pedal distance on-peak anaerobic power and capacity in recumbent cycling.

METHODOLOGY

A variable position seating apparatus constructed with 3 degrees of freedom and

capable of interfacing with a cycle ergometer was used in this investigation. The seating

apparatus allowed for changes in: (1) seat-tube angle (hip angle); (2) trunk angle relative to

the ground (body orientation); and (3) seat-to-pedal distance. The seating position used

was defined by a 75 degree angle formed between the seat-tube and a vertical line passing

through the spindle axis, with the seat-backrest perpendicular to the ground (see Figure 1)

(Too, 1990).

Nineteen male recreational cyclists (ages 20-33 years) were tested in five seat-to-pedal

distance (90, 95, 100, 105, and 110% of the total leg length from the greater trochanter of

the right femur to the ground). Minimum, maximum, mean, and range of hip, knee, and

ankle angles were determined with a goniometer for one complete pedal revolution in each

test condition. All subjects were tested in each of the 5 conditions according to a randomly

determined sequence, with a minimum of 16 hours rest between test sessions. The

Wingate Anaerobic Cycling Test was used on a Monark Cycle ergometer with a resistance

of 85 gm/kg of the subjects' body mass (5.0 joules/pedal rev/kg BM). During the test,

each subject was strapped to the seat-backrest at the waist and hips, pedal toe-clips were

worn, and a micro-switch on-line with a Macpaq analog to digital converter interfaced to a

Macintosh SE microcomputer was used to monitor and record ergometer pedal revolutions.

A computer program, Pacqmanager, was used to collect the data at a rate of 200 samples per second.

Peak anaerobic power was determined by the largest number (or fraction) of pedal revolutions recorded during any successive 5 second interval during the 30 second test. Because the pedal resistance was determined according to each subject's body mass, the recorded number of pedal revolutions represented peak anaerobic power normalized according to body mass. Normalization of peak power allow for comparison with other investigations. This relative peak power was calculated by the following equation: Power (kgm/min) = distance traveled by one flywheel revolution (6 meters per revolution) x flywheel resistance (kg) x pedaling frequency (revolutions per minute). It should be noted that each pedal revolution correspond to one flywheel revolution. Because one watt equals 6.12 kpm/min (Astrand & Rodahl, 1977), the resulting power in kgm/min divided by 6.12 kpm/min converted the units of power to watts (or joules/second); or to simplify calculation of power for any five second interval, the following equation could also be used: Power (watts) = load (kg) x pedal revolutions x 11.765 (Lamb, 1984).

Absolute peak power was then determined by the product of relative peak power and body mass. Anaerobic capacity was determined by the average number of pedal revolutions for the six periods of successive 5 seconds in the 30 second test. This mean relative power represents the maximal capacity to produce energy anaerobically. The total anaerobic capacity was then calculated by the product of the mean relative power and body mass (Lamb, 1984).

Repeated measures ANOVAs were used to determine significant differences in peak anaerobic power and anaerobic capacity with changes in seat-to-pedal distance. Post-hoc tests were used to determine the seat-to-pedal distance which resulted in significantly greater peak anaerobic power and capacity.

RESULTS

The mean hip, knee, and ankle angles (minimum, maximum, average, and range of motion) for the five seat-to-pedal distance are presented in Figure 2. The average angle

was determined from the minimum and maximum angle measured in one complete pedal revolution. It can be observed that all joint angles increased with increasing seat-to-pedal distances, with greater changes occurring at the knee and ankle joint (as evidenced by the increments in range of motion). This would suggest that differences in performance may be attributed to the greater change in knee angle with incrementing seat-to-pedal distances.

The mean absolute peak anaerobic power and capacity for the different seat-to-pedal distances are presented in Figure 3. Anaerobic power (AP) and anaerobic capacity (AC) appear to increase with increases in seat-to-pedal distance. Repeated measures ANOVAs revealed the following significant differences ($p < .05$) with changes in seat-to-pedal distance: AP with $F(4,72) = 27.01$; and AC with $F(4,72) = 28.95$. With the use of post-hoc tests (Fisher PLSD), it was found that AP and AC in the 100, 105, and 110% seat-to-pedal distance were significantly greater than that in the 90 and 95% condition ($p < .05$). However, no significant differences were found in AP or AC between the 100, 105, or 110% seat-to-pedal distance. Trend analysis revealed that with changes in seat-to pedal distance, both, a linear and quadratic function was found to significantly ($p < .001$ and $p < .05$, respectively) describe the trend in AP and AC.

DISCUSSION

For comparative purposes, the optimal seat height for anaerobic work in an upright bicycle was determined to be 109% of the medial aspect of the inside leg from the floor to the symphysis pubis (Hamley & Thomas, 1967; Thomas 1967a,b). For aerobic work, the optimal seat height was reported to be 105-108% of the inside leg from the floor to the symphysis pubis (Shennum & deVries, 1976); 106% of pubic symphysis height (Gregor, Green, & Garhammer, 1981); and 100% of trochanteric height (Nordeen, 1976; Nordeen-Snyder, 1977). The values obtained in this investigation were within the ranges reported in the literature on aerobic and anaerobic work for traditional cycling positions.

Changes in cycling performance with varying in seat-to-pedal distances may be attributed to alterations in the kinematic and kinetic patterns associated with changing joint angles. Changes in seat-to-pedal distance will not only alter joint angles, but also muscle

lengths, muscle moment arm lengths, and resistance arm lengths; which in turn, can affect
the resulting force/torque produced and applied to the bicycle. To investigate these
speculations, it is suggested that EMG activity be monitored for these seat-to-pedal
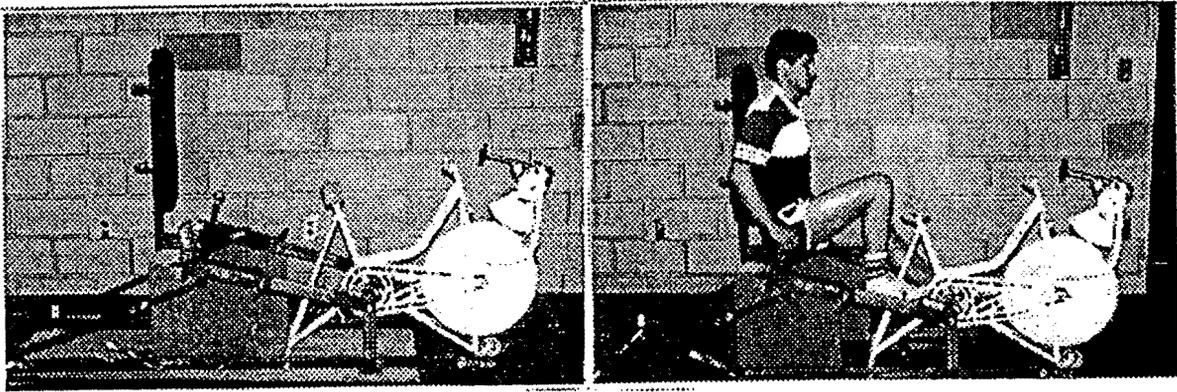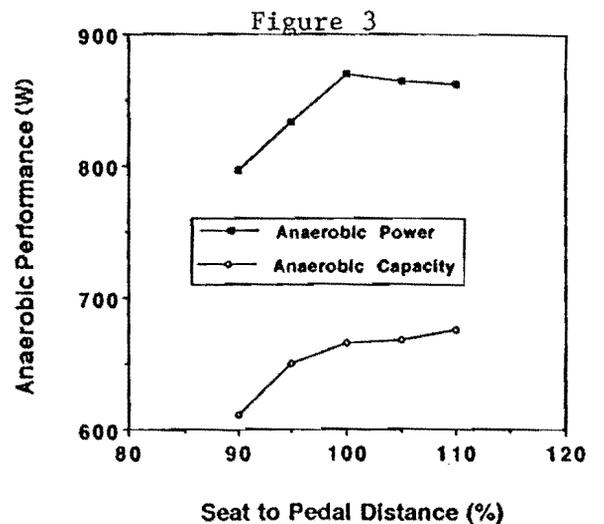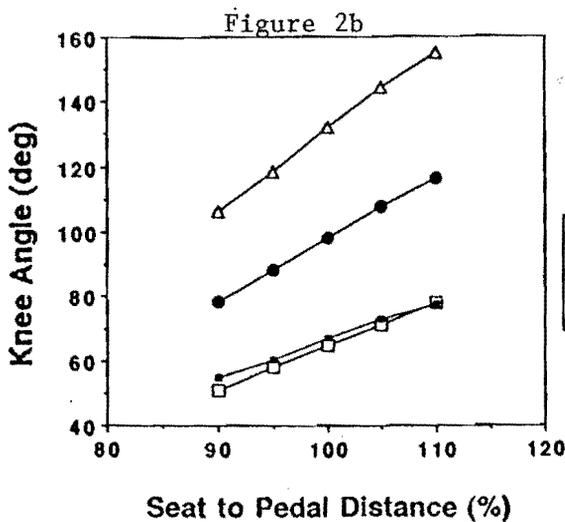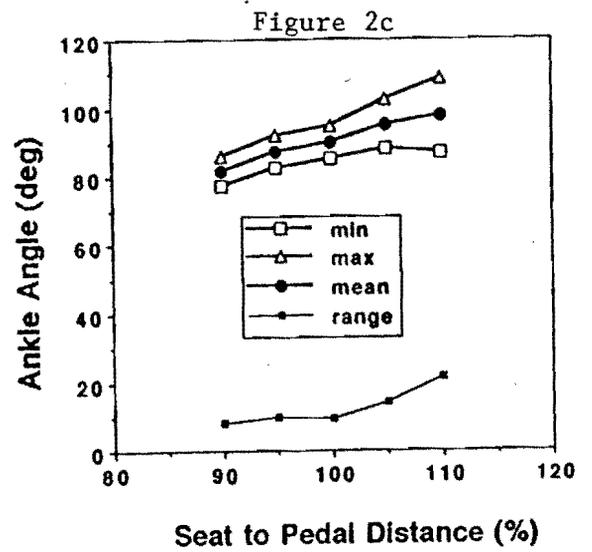distances in future studies.

Figure 1

Figure 2a

Figure 2c

Figure 2b

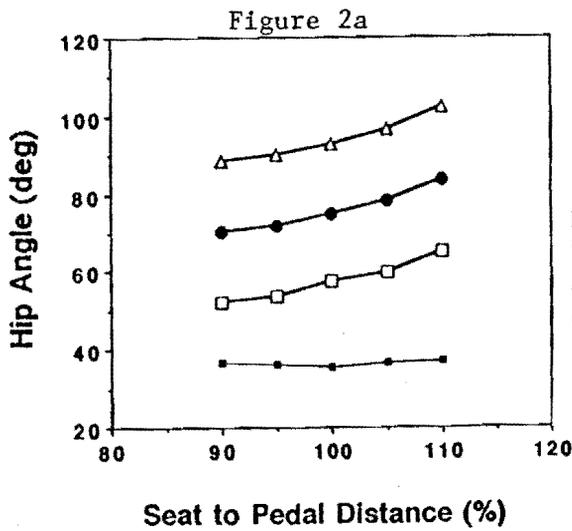Figure 3

Bibliography

Astrand, P.O., & Rodahl, K. (1977). Textbook of Work Physiology, (2nd Ed.). McGraw-Hill Book Company.

Gregor, R.J., Green, D., & Garhammer, J.J. (1981). An electromyographic analysis of selected muscle activity in elite competitive cyclists. In Morecki et al. (Eds.) Biomechanics VII-B (pp. 537-541). Baltimore: University Park Press.

Gross, A. C., Kyle, C. R., & Malewicki, D. J. (1983). The aerodynamics of human-powered land vehicles. Scientific American, 249 (6), 142-152.

Hamley, E.J., & Thomas, V. (1967). Physiological and postural factors in the calibration of the bicycle ergometer. Journal of Physiology, 191, 55-57P.

Kyle, C. R. (1974). The aerodynamics of man powered land vehicles. Proceeding of the Seminar on Planning, Design, and Implementation of Bicycle Pedestrian Facilities (pp. 312-326). San Diego, California.

Kyle, C. R. (1982). Go with the flow: aerodynamics and cycling. Bicycling, 23 (4), 59-60, 62, 64-66.

Kyle, C. R., & Caiozzo, V. J. (1986). Experiments in human ergometry as applied to the design of human powered vehicles. International Journal of Sport Biomechanics, 2, 6-19.

Kyle, C. R., Crawford, C., Nadeau, D. (1973). Factors affecting the speed of a bicycle. C.S.U.L.B. Engineering Report No 73-1.

Kyle, C. R., Crawford, C., & Nadeau, D. (1974). What affects bicycle speed? Part I. Bicycling, 5(7), 22-24.

Lamb, D. A. (1984). Physiology of Exercise: Responses and Adaptations. Macmillan Publishing Company, New York.

Nordeen, K.S. (1976). The effect of bicycle seat height variation upon oxygen consumption and both experimental and simulated lower limb kinematics. Unpublished master's thesis, Pennsylvania State University.

Nordeen-Snyder, K.S. (1977). The effect of bicycle seat height variation upon oxygen consumption and lower limb kinematics. Medicine and Science in Sports, 9, 113-117.

Shennum, P.L., & deVries, H.A. (1976). The effect of saddle height on oxygen consumption during bicycle ergometer work. Medicine and Science in Sports, 8, 119-121.

Thomas, V. (1967a). Saddle height. Cycling, 7, 24.

Thomas, V. (1967b). Scientific setting of saddle position. American Cycling, 6 (4), 12-13.

Too, D. (1990). Biomechanics of cycling and factors affecting performance. <u>Sports Medicine</u>, <u>10</u>(5), 286-302.

Too, D. (1991a). The effect of body orientation on anaerobic power and capacity in cycling. <u>Medicine and Science in Sports and Exercise</u>, <u>23(4)</u>, S7. (Abstract).

Too, D. (1991b). The effect of hip position/configuration on anaerobic power and capacity in cycling. <u>International Journal of Sports Biomechanics, 7(4)</u>, 359-370.

Too, D. (in press). The effect of body position/configuration and orientation on power output. Fourth International Human Powered Vehicle Association Scientific Symposium.

Whitt, F. R., & Wilson, D. G. (1982). <u>Bicycling Science</u> (2nd ed.). Cambridge: M.I.T. Press.

Wilson, B. (1992). Adversity and achievement. The story of setting the record. <u>HVP News</u>, <u>9(6)</u>, 8-9.