HORIZONTAL LEG ORIENTATION AND EXTENDED BODY CONFIGURATION CONTRIBUTE TO THE HIGH EFFICIENCY OF RECUMBENT CYCLING

Hans H.C.M. Savelberg, Paul J.B., Willems and Kenneth Meijer

Dept. Human Movement Sciences, Nutrition and Toxicology Research Institute, Faculty of Health, Medicine and Life Sciences, Maastricht University, Maastricht, The Netherlands; email: hans.savelberg@bw.unimaas.nl

INTRODUCTION

Optimizing cycling performance has been the domain of engineers for a long time. Minimizing aerodynamic drag has been the key issue within this context. However, as argued by Too [1] the human factor should be considered too. Manipulation of body orientation and configuration will affect effectiveness of force production. In recumbent cycling both body orientation and body configuration differ from conventional race cycling. Body orientation refers to the orientation of the body and legs relative to gravity; differences in hip joint angle determine body configuration. The propelling force is determined by muscle work, inertial forces and effects of gravitation [2]. Body orientation will affect the interaction between muscle work and gravity. Due to body configuration the length of muscles as a function of the pedalling cycle will be changed [3].

We hypothesized that both body orientation and configuration affect propelling force during cycling, and that an optimal combination of body configuration and orientation will exist.

METHODS

Ten recreational cyclists participated in this study. All cyclists rode a stationary ergometer in four randomly offered positions: 1. vertically oriented, extended trunk (VE), 2. vertically oriented, flexed trunk (VF), 3 horizontally oriented, extended trunk (HE), 4. horizontally oriented, flexed trunk (HF). In each position the cyclists cycled at a cadence of 70 rpm at 80% of the pre-assessed individual maximal power output.

Pedal reaction forces and leg kinematics were assessed to calculate net joint moments at ankle, knee and hip joint were calculated. Tangential and radial components of the pedal reaction force were calculated. These forces were additionally decompose in a muscular component and a non-muscular component originating from gravitational and inertial effects [2].

RESULTS AND DISCUSSION

Although the average tangential force was similar for each position, the pattern of tangential force was significantly affected by body orientation (fig 1). In both horizontal positions the peak tangential force was significantly smaller and the minimal force was less negative ($p<0.001$); the effective force on the pedal was spread more evenly over the cycle. Consequently, the total work (positive minus negative work) to be generated is lower in the horizontal positions.

Averaged over a cycle, the muscle component contributed much more to the tangential force (~60N) than the gravitational (~0N) and the inertial component (~8N). Body configuration significantly affected the contribution of the three components; in both flexed positions the average contribution of muscles was significantly lower ($p=0.040$) and the inertial component was higher ($p=0.026$) than in the extended positions (fig 2).

Whereas the tangential component of the force effectively propels the cycle, the radial component represents spoiled energy. The average radial force per cycle was significantly lower in the HE position compared to the other conditions (40 vs 53N).

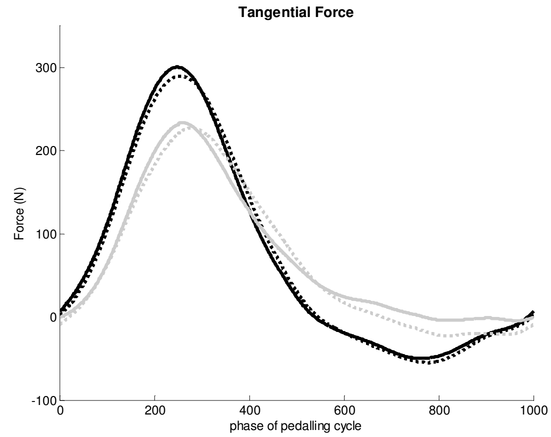

Figure 1: Averaged tangential pedal force as function of the pedal cycle in four positions (solid black: VE; dotted black: VF; solid gray: HE; dotted grey: HF). The beginning of the pedaling cycle is top-dead-centre.

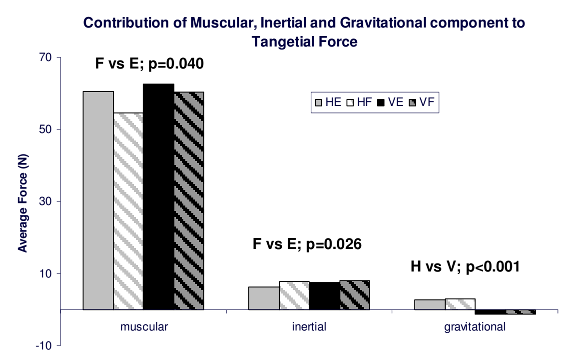

Figure 2: The contribution of the muscular, inertial and gravitational force component to the tangential pedal force.

CONCLUSIONS

This work showed that not only aerodynamic advantages contribute to the relatively high efficiency of recumbent cycling compared to conventional race cycling, but that recumbent positions have physiological advantages too. Moreover this work showed that by manipulating body orientation and configuration cycling performance can be optimized. Both sport cycling and cycling in daily live might benefit from this knowledge.

REFERENCES

1. Too D. *Sports Med.* **10(5)**: 286-302, 1990
2. Kautz SA etal. *J. Biomech.* **26(2)**: 155-165, 1993.
3. Savelberg HHCM etal. *J Appl Biomech.***19**:310-324, 2003.
.