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INFLUENCE OF RACING POSITION ON CYCLING PATTERNS

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The aim of this study was to examine the effect of racing position on the pedal forces, the kinematics of the lower limbs, the muscular joint moments and the muscular joint powers. Cycling in an upright position (UP) and in a dropped position (DP) was analyzed in six subjects during cycling at 200 W with a cadence of 80 rpm. The pedal forces showed only slight differences between the two positions. The kinematic analyses revealed that only the mean hip angle was affected by body position. The inverse dynamics showed that body position significantly influenced the joint powers. The main reason for these changed power outputs could be the change in mean sarcomere length and mean moment arm of the hip muscles with different racing positions.

KEY WORDS: Inverse dynamics, Joint power, Pedal forces, Kinematic.

INTRODUCTION: In endurance cycling, a major goal is to maximize the cycling speed sustainable for a given distance. A variety of internal and external factors can influence cycling speed. Among these, physiological and biomechanical factors influence power production (internal factors), and mechanical and environmental factors affect mainly the relationship between power output and cycling speed (external factors). One of the only variables cyclists can adjust during a race to manage performance is body position. Body position can act both as an external factor and as an internal factor. The effect of body position on the relationship between power output and cycling speed can be calculated with the experimentally measured drag area in different body positions (Jeukendrup & Martin, 2001). From this point of view, an upright posture is clearly detrimental. On the other hand, racing position in cycling could also act as an internal biomechanical factor influencing cycling patterns and power production. Some experimental studies have already shown that body position can significantly affect power output in endurance cycling (Jobson et al., 2008, unpublished work from our institute). The exact mechanisms underlying the increased power output with a more upright posture have not been analyzed in detail. Dorel et al. (2009) analyzed the influence of body position on the effective pedal force and on electromyographic patterns during cycling, but they did not measure the kinematics of the limbs nor the ineffective pedal force.The main goal of this study was to examine the effect of racing position on the pedal forces, the kinematics of the lower limbs, the muscular joint moments and the muscular joint powers.

METHODS: Six well-trained male amateur cyclists (28 ± 3 years, 180.3 ± 3.1 cm, and 68.3 ± 7.1 kg) performed a cycling trial at 200 W with a cadence of 80 rpm in two racing positions: upright posture (UP) with hands on the top portion of the handlebars and arms fully extended and dropped posture (DP) with hands on the drops of the handlebars and arms fully extended (Fig. 1). The position and orientation of the pelvis and the segment lengths (thigh, shank, and foot) were measured statically (Fig. 1). Both pedals were equipped with a force measurement device that measured the parallel and normal component of the pedal force using strain gauges. Furthermore the pedal angle and the crank angle were measured using angular potentiometers. Hence the resultant pedal force can be subdivided into the tangential pedal force and the radial pedal force (Fig. 2). Joint-specific angles and angular velocities were then calculated using inverse kinematics. The measured and calculated forces and kinematics needed for the inverse dynamics were averaged over ten pedal revolutions. The minimal and maximal values of the variables over a complete pedaling revolution were analyzed. Joint-specific muscular moments and powers were then calculated using inverse dynamics and averaged over complete pedal revolutions (P_{joint}) and over the regions with positive ($P_{joint,p}$) and negative muscular power ($P_{joint,n}$). The positive and negative powers were further differentiated into extension ($P_{joint,p,e}$, $P_{joint,n,e}$) and flexion phases ($P_{joint,p,f}$, $P_{joint,n,f}$). All statistical analyses were performed using SPSS Statistics 17 (SPSS Inc., Chicago, USA). The level of significance was set at α = 0.05. Values between the body positions were compared using Student's paired t-tests.

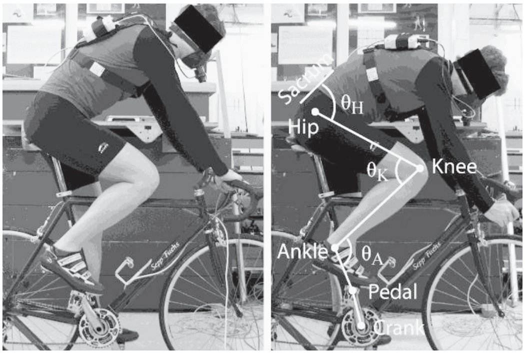

Figure 1: The two tested racing positions: upright posture with hands on the top portion of the handlebar (UP, left side) and dropped posture with the hands on the drops of the handlebar (DP, right side). On the right side is a schematic representation of the markers and angles used. The lower limb was modeled as a 3-segment (thigh, shank, and foot) rigid-body system. The foot link is an imaginary line connecting the ankle and the pedal spindle, and not the actual foot segment. The angle between the shank and the imaginary foot link is defined here as ankle angle (Bini & Diefenthaeler, 2010). The orientation of the pelvis was estimated by the orientation of the sacrum line. θ_H, hip angle; θ_K, knee angle; θ_A, ankle angle.

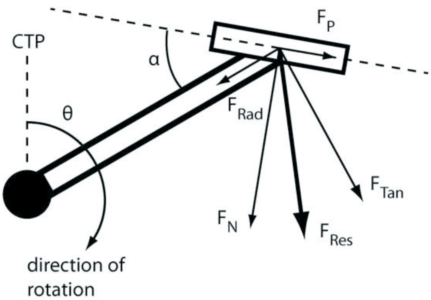

Figure 2: Representation of the different pedal forces. With the two measured forces (F_P: parallel force; F_N: normal force), we obtained the resultant pedal force (F_{Res}). With the measured pedal angle (α), this force vector can be subdivided into the tangential pedal force (F_{Tan}; effective force causing rotation) and the radial pedal force (F_{Rad}; ineffective force). CTP, crank top position; θ, crank angle.

RESULTS: The minimal and maximal values of the kinematics (joint angles and joint angular velocities) showed no significant influence of body position except for the hip angles. The minimal and maximal hip angles were 8.1 ± 1.6° greater for UP compared to DP.

The minimal and maximal values of the pedal forces (tangential, radial, and resultant force) showed no significant influence of body position except for the minimal radial force (Fig. 3). This force was 15 ± 10N greater for UP compared to DP.

The calculated joint-specific muscular powers over the complete pedal revolution showed that P_{hip} was significantly greater for DP (60 ± 15W) compared to UP (53 ± 14W), P_{knee} was significantly lower for DP (30 ± 13W) compared to UP (39 ± 13W), and P_{ankle} was unaffected by body position. Averaging the joint powers over the regions with positive and negative muscular power the analysis showed a significant influence of body position on $P_{hip,p}$, $P_{knee,p}$, and $P_{knee,n}$ (Fig. 4). The further differentiation of the positive and negative joint powers into extension and flexion phases showed that $P_{hip,p,e}$, $P_{knee,p,e}$, and $P_{knee,n,e}$ were significantly affected by body position (Fig. 5).

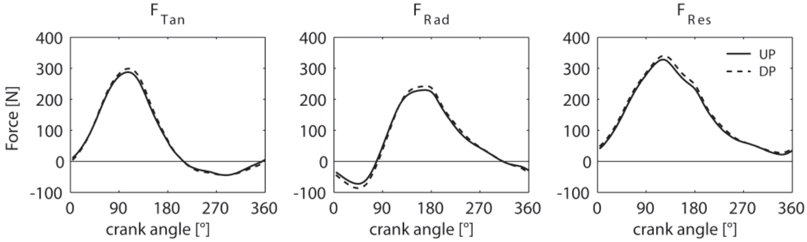

Figure 3: Mean profile of the pedal forces (F_{tan}: tangential force, F_{Rad}: radial force, F_{Res}: resultant force) measured in the two positions (UP, upright posture – solid line; DP, dropped posture – dashed line) for all the subjects.

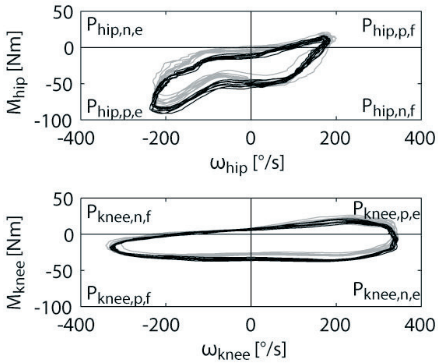

Figure 4: The muscular joint moments in relation to the joint angular velocities for the hip and knee joint over ten pedaling revolutions of a single representative subject. The grey line represents UP and the black line DP. The four quadrants represent the positive and negative power during the extension ($P_{joint,p,e}$, $P_{joint,n,e}$) and flexion phases ($P_{joint,p,f}$, $P_{joint,n,f}$).

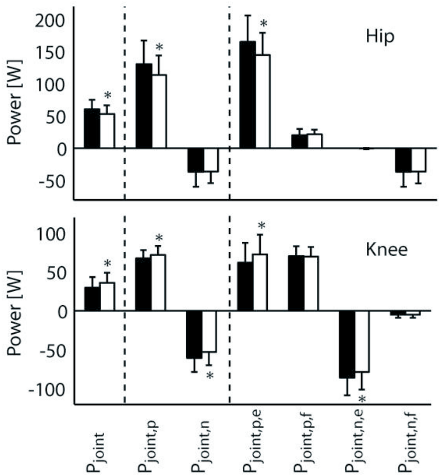

Figure 5: The muscular joint powers of the hip and of the knee in the dropped posture (DP, black) and in the upright posture (UP, white). Joint powers were averaged over complete pedal revolutions (P_{joint}) and over the regions with positive ($P_{joint,p}$) and negative muscular power ($P_{joint,n}$). The positive and negative powers were further differentiated into extension ($P_{joint,p,e}$, $P_{joint,n,e}$) and flexion phases ($P_{joint,p,f}$, $P_{joint,n,f}$). *significantly different from DP ($p < 0.05$).

DISCUSSION: The kinematic results of the experiments showed that the mean hip angle was 8.1° greater for the upright compared to the dropped position, a finding in agreement with other studies (Sauer et al., 2007). The kinematic results also showed that only the mean hip angle was affected by the change in body position. This finding means that body position did not influence the pedaling pattern of the lower limbs. Thus, the main change in the calculated joint powers must have the origin in the intrinsic power-producing capabilities of the uniarticular and biarticular hip muscles. The reason for these changes could be a change in mean sarcomere length and mean moment arm of the hip muscles with the different racing positions. This assumption is based on the well-known force–length relationship of muscles with a force maximum at an intermediary length of about 1.05 times the “rest length.” In conceptual work, different authors have demonstrated that the force of the contractile element is a product relationship between the two phenomena of force–length and force–velocity (Winters, 1990). Thus, when discussing muscle power output, the aspect of sarcomere length and joint angle must be considered.

CONCLUSION: The change of body position did not alter the kinematic pedaling pattern except for the mean hip angle. Thus, the reason for a changed power output with different body positions should have the origin in mean sarcomere length and mean moment arm of the hip muscles with different racing positions. The results of this study bring new insight to the topic of racing performance and body position. Further theoretical studies with model simulations should provide a better view of the exact mechanisms underlying the observed changes in power output with different body positions.

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