INFLUENCE OF AN ERGOLINE BICYCLE ERGOMETER ON BODY SEGMENT KINEMATIC AND POSTURE

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INTRODUCTION

Bicycle ergometers have been the most used modality in the investigation of physiological and biomechanical parameters in cycling, because they can provide standardized procedures that are simple and inexpensive, and for their ease of calibration and adaptation to various body size. In addition, the possibility to apply racing type saddles, handlebars, and pedals allows the athlete to more closely replicate road racing conditions in laboratory.

However, all these modifications do not allow cyclists to feel completely comfortable with the testing equipment. Competitive cyclists typically find it difficult to assume their normal riding position on most commercially manufactured cycle ergometers.

If a rider cannot assume his/her normal position, work output may be decreased (Firth, 1981). Changes in body position have been shown to result in changes in the range of motion in hip, knee and ankle joints (Noorden and Cavanagh, 1976). Angular velocities of body segments in these joints change accordingly. These changes will affect the shortening range and velocities of the muscles that cross these joints and this in turn may have an effect on power output. Bending the trunk more or less has been shown to have an effect on the circulatory system (Faria et al., 1978) and power output (Kyle and Caiozzo, 1986) during cycling exercises. An efficient and powerful position is one that enables the cyclist to pedal the bicycle effectively without a lot of wasted energy and improper pedaling mechanics.

The latter point is imperative not only for comfort but also for minimizing potential for injury. Improper positioning can often lead to overuse injuries and premature fatigue while riding. This is also important because, very often, medical doctors and physiotherapists suggest the use of bicycle ergometers for rehabilitation and re-education of subjects after an injury and for people who should better not practice other antigravitational sport activities.

To date, there is very little information about the effects of bicycle ergometers on body kinematics. By a simultaneous right and left 3-D kinematic analysis, the purpose of this study is to compare body segment kinematic and posture of five experienced cyclists while pedalling on their own racing bicycle and on a popular bicycle ergometer.

METHODS

Five experienced road cyclists, (age: 27.7 ± 3.6 yr.; height: 179 ± 5 cm; body mass: 67 ± 4.9 kg), usually covering more than 30.000 km/year, were the subjects of this study. Each athlete, first pedalled on his own bicycle mounted on rollers fitted with an air-operated variable-load device and then, performed on an electronically braked cycle ergometer (Ergoline, Germany) which was mechanically modified to allow the athletes to correctly adjust the seat and handlebar, and to use their normal cycling shoes and cleats. Every acquisition lasted twelve seconds with the subjects pedalling at 90-95 rpm.

The ELITE system motion analyzer (Ferrigno & Pedotti, 1985), with 4 TV cameras paired on the two sides of the cyclist to allow a double side 3-D analysis, was used to record, at a sampling frequency of 100 Hz., the 3-D coordinates of small retroreflective markers positioned on 19 anatomical repere points. Size of the passive retroreflective markers was 10 mm in diameter.

The 3-D body coordinates (iliac crests, great trochanters, femoral condiles, malleola, fifth metatarsal heads to mark the pelvis and the lower limbs; acromions; elbows, and wrists to mark the arms, and C7, T10, L5 to reconstruct the trunk) and some anthropometric measures of the subject were the input of a mathematical model, providing the spatial kinematics of thirteen rigid segments belonging to the lower limbs (feet, shanks, thighs and pelvis, lower and upper trunk, arms and forearms), designed to match feasibility with accuracy. Due to the inevitable simplifications introduced, the use of the model is constrained to movement in which large rotation of body segments around their longitudinal axes are negligible like running, cycling and vertical jumping exercises.

All the collected data are used as input for the computer program CICLO which was written in Matlab (4.2b version for Windows) and specifically developed to perform a complete 3-D kinematic analysis in cycling.

The program, by identifying the main pedalling cycle events and normalizing the time over the pedalling cycle (for this purpose cubic spline interpolation is applied to the original data points to obtain 100 samples per pedalling cycle independently from its actual duration), is capable of producing automatically a large amount of data: 1) joint rotation centre trajectories in the sagittal, frontal, and horizontal plane; baricenter of the trajectories; displacements from the bicycle frame, 2) relative joint and absolute segment angles in the frontal and sagittal plane, 3) pelvis orientation, 4) comparison between left and right patterns; asymmetry indexes. The software package also includes a relational database written in C for the management of the quantitative and statistical comparison among the computed kinematic indexes.

To evaluate if the variables considered were significantly different between the two conditions the Wilcoxon signed rank test was used. The level of significance was set at 5%.

RESULTS AND DISCUSSION

An examination of the kinematic patterns of the lower limbs in the sagittal plane indicated that the major differences occur at the hip and ankle joint. The pattern of motion of the knee showed no variation. It appears that the adaptations at both the hip and ankle combine in such a way that no change in the cyclist's knee patterns is seen.

As it can be seen in the Table 1, considering lower limb joint motion in the sagittal plane, significant differences between the two pedalling conditions were found in the ankle range of motion (ROM) and in maximum (MAX) and minimum (MIN) angular hip flexion.

Table 1. ROM refers to the range of motion and MAX and MIN refers to the maximum and minimum angular joint flexion.

	ROM (degrees)		MAX (degrees)		MIN (degrees)	
	Bicycle	Ergoline	Bicycle	Ergoline	Bicycle	Ergoline
Hip	39(2.5)	37(3.1)	139(4.3)	148(5.0)*	100(4.5)	111(4.1)*
Knee	69(2.1)	70(2.6)	145(4.4)	146(4.1)	77(5.1)	80(5.7)
Ankle	22(1.8)	18(2.1)*	118(5.1)	120(5.3)	97(4.9)	101(4.4)

Other relevant differences were evident in examining joint rotation center trajectories in the frontal plane, with the foot and shank performing farther from the bicycle frame using the Ergoline. This may be easily seen in Table 2 where the distance between the baricenter of the knee and ankle rotation center trajectories and the bicycle frame are reported. In most of the subjects this resulted in an excessive transverse/frontal knee motion.

The displacement of the knee joint was more than 100 mm in the frontal plane. This leads to an internal torsion of the tibia and adduction of the thigh that result in irritating force and stress on the structures on both the medial and lateral sides of the knee. Table 3 shows some of the variables related to the knee angular joint motion in the frontal plane, while in Figure 1, the knee angular displacement in the frontal plane for a representative subject of this study is reported.

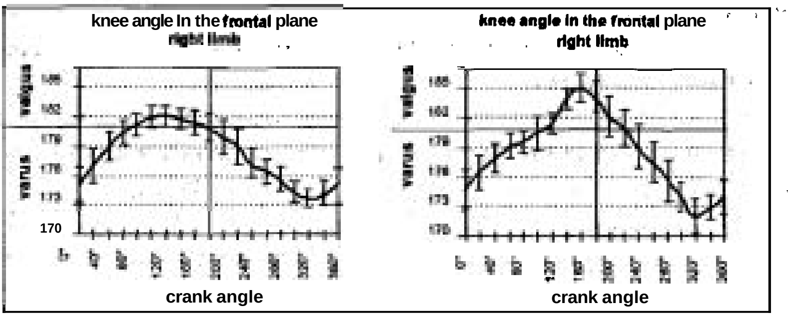
Table 2. Distance (in mm) between the baricenter of the knee and the ankle rotation center trajectories and the bicycle frame in the frontal plane.

	baricenter		top dead point		bottom dead point	
	Bicycle	Ergoline	Bicycle	Ergoline	Bicycle	Ergoline
Knee	110(8)	178(10)*	122(10)	231(14)*	98(9)	126(12)*
Ankle	125(9)	172(10)*	128(8)	201(11)*	123(8)	159 (10)*

Table 3. Knee range of motion (ROM), and maximum (MAX), and minimum (MIN) angular knee valgus angles in the frontal plane.

ROM(degrees)		MAX(degrees)		MIN(degrees)	
Bicycle	Ergoline	Bicycle	Ergoline	Bicycle	Ergoline
6.6 (2)	10.8 (3)*	182 (4)	187 (6)*	175(4.5)	176 (5)

The pelvis is significantly less anteroversed on the bicycle ergometer with more pelvic tilt in the frontal and horizontal plane. The trunk inclination resulted lower in the ergometer condition with a more pronounced angle between the lower and upper part of the trunk. The less anteroversed hip position on the ergometer may explain the differences in hip angle being this last variable largely affected by pelvis tilting.



Road bicycle — Ergoline ergometer

Figure 1. Knee angular patterns in the frontal plane for a representative subject pedalling on his road bicycle and on the Ergoline.

CONCLUSIONS

The method presented here seems to be a useful tool to assess and to evaluate biomechanical data during cycling both on the road bicycle and on the Ergoline ergometer. The proposed kinematic model gives indeed a good representation of the cyclist during his action, and the developed software allows to analyze the data in a short time.

In summary, the examination of the kinematic patterns of the lower limbs indicates that, in the sagittal plane, the major adaptation to the ergometer occurs at the hip. This is not surprising considering that the motion of this joint is highly affected by both the pelvis tilting and trunk inclination. In addition, the use of the examined ergometer significantly alter lower limb kinematics in the frontal plane compared to standard racing bicycle, leading to an excessive torsion of the tibia and a valgus position of the knee which, in turn, can precipitate injuries at the lateral structures of this joint. This point must be considered for minimizing potential for injury and premature fatigue when this device is used for training and/or to collect physiological and biomechanical data. Even more caution should be taken when this device is used for rehabilitation purpose for knee and ankle injuries.

Further studies should include EMG analysis and the measurements of the force applied at the pedals by the rider for lower limb joint kinetic motor output (powers and moments of force) calculation.

REFERENCES

Cavanagh, P.R., & Sanderson, D.J. (1986). Science of cycling (pp. 91-122). Champaign, IL: Human Kinetics.

Faria, I.E., Dix, C., & Fraxer, C. (1978). Effect of body position during cycling on heart rate, pulmonary ventilation, oxygen uptake and work output. Journal of Sports Medicine and Physical Fitness 18, 49-56.

Ferrigno, G., & Pedotti, A. (1985). ELITE a digital dedicated hardware for movement analysis via real time TV signal processing. IEEE Trans. Biomedical, 32, 943-950.

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