A SPECIAL MOTION AND PERFORMANCE ANALYSIS OF PROFESSIONAL CYCLIST

Zsolt Knoll MD[1], Rita Kiss PhD.,CSc.[2] , István Györe MD.[3], László Kocsis PhD.[4], Mihály Jurák [4]
[1]Fund MEDICAMENTOR, Budapest, Hungary, [2]Academic Group of Structures, Budapest, Hungary, [3]National Institute of Sport Medicine, Budapest Hungary, [4]BUTE Department of Applied Mechanics, Budapest, Hungary

The biomechanical analysis of sport-motion is a new joint research field of biomechanics and sport medicine. Each cyclist was examined at an own bike mounted on an ergometer for analyzing the motion and the muscle activity at different loading. The ultrasound-based 3D motion analysis-system and surface EMG signals were used to measure the motion parameters during the cycling. The kinematical parameters, such as the knee angle, and the muscle activity of four muscle groups were determined in every cycle of pedaling. The lactic-acid amount of the capillary-blood and the pulse were checked during the exercise. On the basis of the analysis, it can be established that the movement and the muscle activity are disordered close to the anaerobic threshold; thereafter, they become ordered. The results of the examination give effective help to trainers and athletes to improve the performance.

KEY WORDS: biomechanics, motion analysis, cycling, EMG.

IINTRODUCTION: The specialists of human genetics, of nutrition-science, of sport-surgery, of rehabilitation, of sport medicine and of sports-equipment's manufactures use every effort to increase the performance of the professional athletes. Biomechanics plays an important role in the development of sports equipment, for example in developing a new bicycle pedal (Boyd *et al.*, 1997, Wolchok *et al.*, 1998). Biomechanics has an important role in the analysis of sport-motion, because the modeling of motion and developing of an ideal motion allow to increase the sport-performance. A number of studies examine special questions such as the effect of asymmetry (Smak, *et al.*, 1999), the effect of type of pedaling (Wolchok *et al.*, 1998) or muscle coordination (Neptune and Herzog, 2000) in cycling. The specific goal of the present analysis was to detect the changing of motion and of muscle activity during an increasing loading (pedal rating). The motion analysis was combined with a physiological test (measurement of lactic-acid amount of capillary blood and of pulse).

METHODS: The subjects of study were nine male professional cyclists. The age was 25,8±5,6; the height 180,3±5,9 centimeters, the weight 708±59 Newton, the oxygen consumption 70,2±7,2ml/min/kg and the fat percent 13,2±1,8. The own bicycle was mounted on an ergometer that provides a constant workrate (i.e. average power). The protocol consists of 10 min warm-up period at a work-rate of one watt-per-bodyweight followed by 3 minutes at two watt-per-body weight, after which power output increased by one watt-per-body weight every 3 minutes. The lactic-acid amount of the capillary blood was determined before the exercise, after all loading step and 5 minutes after finishing the exercise. The pulse of cyclist was measured in every minute from the start of exercise until 5 minutes after the finishing of the exercise. The procedure for determination of lactic-acid amount is based on the spectrophotometic determination of NADH using a specific D-lactic dehydrogenase to catalyzed the formation of pyruvate. The ZEBRIS *CMS-HS* measuring system was used for complex 3D real-time measuring of cycling motion. A general, 19-point-biomechanical-model for analysis of lower extremities' motion, developed in the Biomechanical Laboratory at the Budapest University of Technology and Economics, was used. The model considers each limb segment to be a rigid body, linked to each other by a joint. The triplets are attached to the segments and (virtually) linked to the anatomical points in such a way, that the registered movement of each triplet enables the calculation of the position of anatomical points, and thereby representing the movement of each limb segment. (Kocsis & Jurak, 2002). For the 19-point-model, using 15 active marker points (5 triplets), which are attached to the sacrum, right and left thigh, and right and left calf (Figure 1). The location of the investigated anatomical points and their associated triplets are summarized on Figure 2. The sampling rate of the measurement is 50Hz.

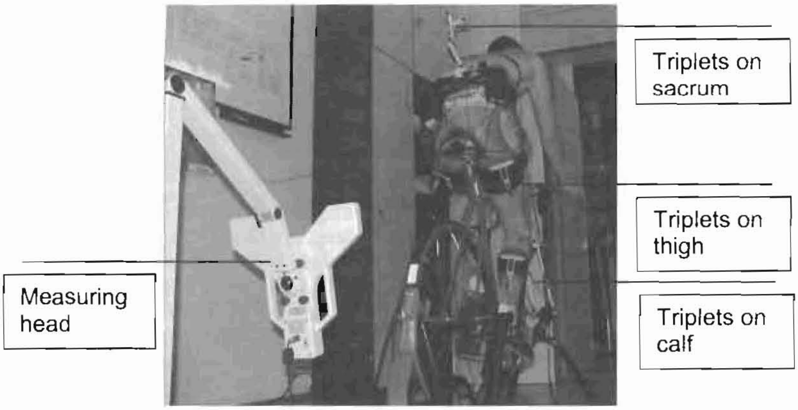

Figure 1. Configuration of the triplets and one measuring head positioned at the back of the subject.

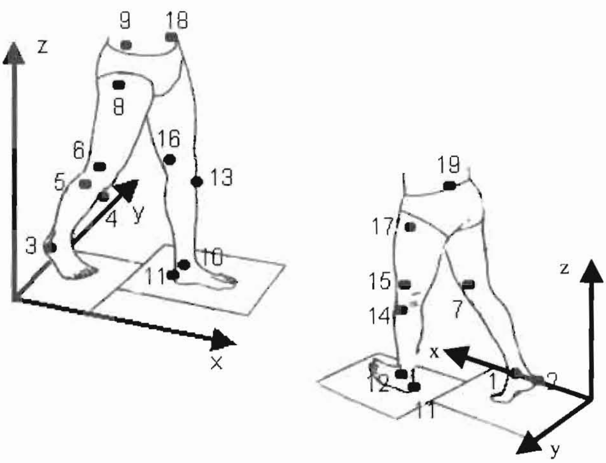

Figure 2. Position of the anatomical points. (1) right medial malleolus, (2) right heel, (3) right lateral malleolus, (4) right tibial tubercule, (5) right fibula head, (6) right lateral femoral epicondyle, (7) right medial femoral epicondyle (8) right great trochanter, (9) right ASIS, (10) left medial malleolus, (11) left heel, (12) left lateral malleolus, (13) left tibial tubercule, (14) left fibula head, (15) left lateral femoral epicondyle, (16) left medial femoral epicondyle (17) right great trochanter, (18) left ASIS, (19) sacrum.

The surface EMG electrodes were apposed to m. vastus medialis, m. hamstring, m. gluteus maximus and m. gastrocnemus med. The registered action, potential of each electrode, enables the representing the muscles activity. The data were collected by 450Hz sampling rate in the last 30 seconds of every loading step. The measurement system was used to process the recording of the lower limb anatomical movements and of EMG data. The outputs of the measurement are the spatial coordinates of the anatomical point and the raw data of EMG signal. The raw data were smoothed by ReharobManager, which is a general post-processing software developed for zebris CMS-HS measurement system (Kocsis & Jurak, 2002). The flexion-extension motion is characterized by the knee's angle-time function. The knee angle is defined as the angle between a straight line joining lateral malleolus – fibula head and a straight line joining lateral femoral epicondyle – great trochanter and calculated from the spatial coordinates of the anatomical points. The muscle activity is characterized by

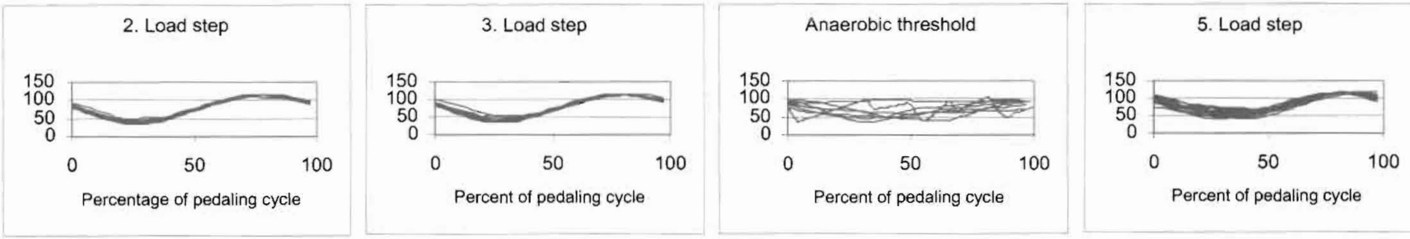

Figure 3. The knee-angle function of percent of cycle at different work-rate.

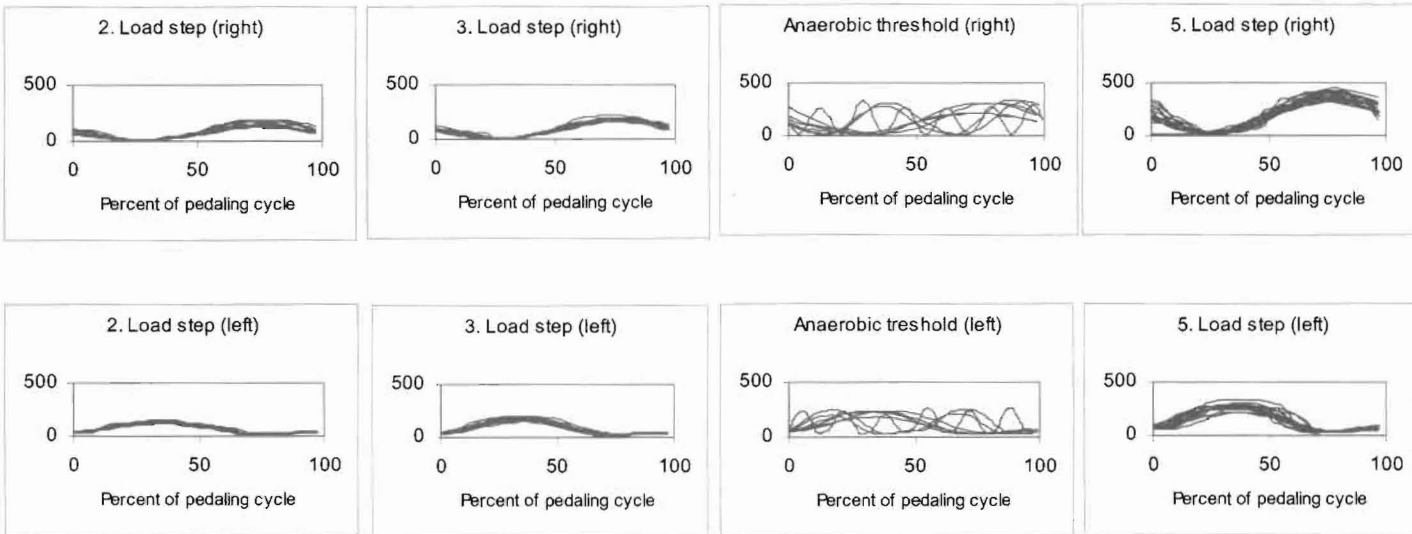

Figure 4. The EMG envelope curve of muscle vastus medialis in function of percent of cycle at different work-rate.

EMG envelope-curve in time function. For EMG analysis in our Laboratory the method of linear filtering is used (Kocsis & Jurak, 2002).

RESULTS AND DISCUSSION: Firstly, the critical loading-step for anaerobic threshold of each cyclist was determined from lactic acid amount of the capillary blood and from the pulse. Secondly, the knee-angle and the EMG-envelope curves were calculated in each loading step's last 30 seconds. Figure 3 and 4 display typical curves of knee-angle and EMG envelope in function of percent of pedaling-cycle. That is to say, on one chart curves the whole pedaling cycle can be shown, these curves are detected in the last 30 seconds of the given loading step. On basis of the analyzing the results we can establish the followings

- The deviance of the knee angles increase by increase of the work-rate, of pedaling rate (Figure 3). The deviance of the knee angle in the first load step is 1.20-3.14 degree, in the second 4.44-5.89 degree, in anaerobic threshold is indefinite, after the threshold is 17.90-24.80 degree.
- The movements and the muscle activity are disordered at the anaerobic threshold determined from the lactic acid amount and from the pulse. Thereafter, both the movement and the muscle activity become ordered; however the characteristic of the curves differs from the curves in aerobic stage (Figure 3 and 4)
- The activity of muscle gluteus max. increased in the anaerobic stage.
- The deviance of the calculated parameters is individual, the changing in the training program has to be individual too.

CONCLUSION: The paper presents an integrated physiological-motion-EMG analysis of professional cyclists. Once the model was used, we could detect that the anaerobic threshold determined by the physiological test and the motion disorders occur in the same loading step at every examined cyclist.

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