EFFECT OF LATERALLY MOVEABLE PEDALS (BIUS) ON KINEMATICS, PEDAL FORCES AND MUSCLE ACTIVITY IN RECREATIONAL CYCLING

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The purpose of this study was to investigate the effect of a laterally moveable pedal on the kinematics, kinetics and muscle activity in recreational cycling compared to cycling with a standard pedal on an ergometer. Four healthy participants cycled at 100 W and 200 W at 80 rpm with a standard and the BIUS pedal. Kinematics, kinetics and muscle activation have been measured in both conditions. No differences were found regarding the joint angles and in the lateral movement of the pedal. Some differences were partly observed for the ground reaction forces and the muscle activation pattern. In the ergometer setting the BIUS pedal does not lead to kinematic changes of the cycling movement, but causes effects on pedal forces and muscle activation.

KEY WORDS: cycling, pedals, pedal forces, EMG.

INTRODUCTION: The knee joint is one of the most affected regions regarding overload injuries in cycling (Clarsen et al., 2010; Schwellnus & Derman, 2005; Wilber et al., 1995). This is true for both, for elite and recreational setting. The one-dimensional cycling movement in a closed kinematic chain is assessed as severe restriction of the natural, three-dimensional lower extremity joint kinematics causing the aforementioned pain or overload injuries in the knee joint structures. One preventive measure to overcome this potential risk was the development of the BIUS pedals (Figure 1).

Figure 1: BIUS pedal

These pedals are mounted on the axle in such a way that the pedals are moveable about 25 mm each in medio-lateral direction from the neutral position by compressing springs located between the axle and the pedal. The variable medio-lateral position of the pedal allows a tibio-femoral rotation during the flexion/extension motion in cycling. These theoretical considerations have not been investigated so far from a biomechanical point of view in practical cycling. Therefore, the purpose of this study was to investigate the effect of the BIUS pedal on the kinematics, kinetics and muscle activity in recreational cycling compared to cycling with a standard pedal.

METHODS: Four healthy male participants (24 ± 2 yrs, 71 ± 11 kg, 1.76 ± 0.08 m) took part in the study. They were asked to cycle on an SRM Ergometer (Schoberer Rad Messtechnik SRM GmbH, Jülich, Germany) at 100 W and 200 W at 80 rpm in two pedal conditions: (1)

standard pedal, (2) BIUS pedal. The condition at 150 W was used for individual and muscle specific normalization of the EMG signal.

The kinematics was measured with eight Vicon cameras (Vicon Motion Systems Ltd., Oxford, UK) with a sampling rate of 250 Hz based on the Cleveland Clinic marker set. The pedal forces were measured with Pedar insoles (novel GmbH, Munich, Germany) with a sampling rate of 100 Hz. Myon EMG (myon AG, Schwarzenberg, Switzerland) with 1 kHz sampling rate was used for measuring the muscle activity of the following muscles (left limb) according to recommendations from the literature (Mehl, 2008; Neptune et al., 1997): m. glutaeus medius (GL), m. rectus femoris (RF), m. vastus medialis (VM), m. biceps femoris (BF), m. semitendinosus (ST), m. tibialis anterior (TA), m. gastrocnemius medialis (VM). The EMG signals were collected simultaneously and synchronized with the kinematic data. The synchronization with the kinetic system was implemented using an external trigger signal.

All data sets were processed by averaging ten consecutive cycles. The kinematic and the EMG data were further processed with Visual 3D (C-Motion Inc., Newtown Linford, UK). The Range of Motion (ROM) of the knee joint was calculated for the sagittal, frontal and the transversal plane. The medio-lateral distance of the pedal was determined by the lateral marker position of the marker on the fifth metatarsal head. Based on the export of the kinetic data the maximal and average forces were calculated and normalized to body mass using Matlab (Mathworks Inc., Massachusetts, USA). The intensity of muscle activation was normalized to the mean of the reference measurement at 150 W (Kroell et al., 2010), rectified and RMS-filtered (window width: 25 ms). The activation pattern was determined using an onset of 20% of the activity of the reference peak value for each muscle (Baum et al., 2003). The pedaling cycle was separated and averaged in the phases downward (45-135°) and backward (135-225°). T-tests for paired samples were used for checking the means regarding significant differences.

RESULTS: None of the kinematic measures demonstrated substantial and significant differences between the two pedal settings, neither for the 100 W nor for the 200 W conditions. Table 1 presents the pedal forces and EMG activity of lower extremity leg muscles in cycling with standard and BIUS pedals during the downward and backward phase in the 200 W condition. Cycling with BIUS leads to higher average pedal forces in the downward and in the backward phase. The differences, however, are significant for the downward phase only. The muscle activation differs between cycling with the standard and with the BIUS pedal, but only one significant differences was detected (vastus medialis in the downward phase). Similar results were found for the 100 W condition.

Table 1: Pedal forces and EMG activity of lower extremity leg muscles in cycling with standard and with BIUS pedals. The numbers represent the average values over the downward and backward phase (mean ± standard deviation, n=4).

	downward phase		backward phase	
	standard	BIUS	standard	BIUS
Pedal forces [N/kg]	2.00 ± 0.84	2.39 ± 0.71*	1.38 ± 0.49	1.59 ± 0.26
Gluteus maximus [V/V]	1.23 ± 0.23	1.49 ± 0.61	0.65 ± 0.38	0.73 ± 0.41
Rectus femoris [V/V]	0.92 ± 0.40	0.90 ± 0.23	0.29 ± 0.09	0.31 ± 0.10
Vastus medialis [V/V]	1.49 ± 0.20	1.36 ± 0.21*	0.20 ± 0.05	0.20 ± 0.19
Semitendinosus [V/V]	1.09 ± 0.34	1.10 ± 0.18	1.15 ± 1.00	1.12 ± 0.75
Biceps femoris [V/V]	1.20 ± 0.29	1.04 ± 0.27	0.89 ± 0.44	0.91 ± 0.37
Tibialis anterior [V/V]	0.50 ± 0.06	0.53 ± 0.06	0.72 ± 0.53	0.97 ± 0.89
Gastrocnemius medialis [V/V]	1.55 ± 0.41	1.47 ± 0.48	1.23 ± 0.08	1.10 ± 0.47

The muscle activity pattern (also demonstrating the muscle coordination) for the 200 W condition is comparatively presented in Figure 2. For most of the muscles the onset of activation starts in the forward phase and slightly earlier when cycling with the BIUS pedals. This was similar when cycling in the 100 W condition.

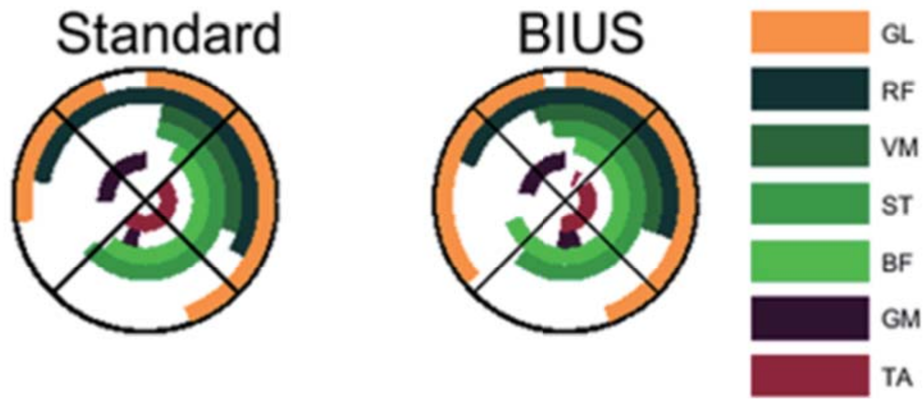

Figure 2: Muscle activation pattern when cycling with standard and BIUS pedals at 200 W (n=4)

DISCUSSION: The purpose of the study was to investigate the effect of the BIUS pedal on the kinematics, kinetics and muscle activity in recreational cycling compared to cycling with a standard pedal. Neither the joint angles nor the lateral displacement of the pedal showed significant differences between the two pedal conditions. The participants cycled on an ergometer and, thus, in a quite stable situation. This might have caused a more or less stable cycling pattern without moving the pedal in the medio-lateral direction in case of the BIUS condition. Based on this it is even more remarkable that the forces applied to the pedal in the downward phase and the muscle activation pattern show several and in two cases also significant differences between the two pedal conditions. It seems that the muscle activation is coordinated in such a way that the same kinematic output can be achieved in the "unstable" BIUS condition. As a speculation, the results might be different in case of free cycling in field conditions when the bike is not supported anterior-posteriorly and medio-laterally. Furthermore, the small sample size of four participants does not allow for clear conclusions in this matter.

CONCLUSION: Cycling with BIUS pedals does not lead to kinematic, but partly significant changes in the forces application and muscle activation pattern compared to cycling with standard pedals in an ergometer setting. The expected tibia rotation when cycling with BIUS cannot be supported by this study. A study in free cycling conditions might serve deeper insights into effect of laterally moveable pedals on kinematics, kinetics and muscle activation.

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