EFFECT OF DIFFERENT CYCLING CONDITIONS ON SAGITALL AND FRONTAL LOWER LIMB KINEMATICS OF COMPETITIVE AND RECREATIONAL CYCLISTS

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The aim of the current study was to compare sagittal and frontal hip, knee and ankle joint kinematics between competitive and recreational road cyclists across different workloads and pedalling cadences. Five competitive and five recreational healthy male road cyclists performed four conditions (85 rpm and 95 rpm at 200 W and 65 rpm and 75 rpm at 230 W) in random order to cover a variety cadences and workloads used during competition or training (plane, slight hill, medium hill and steep hill). Lower limb kinematic data were collected with nine infrared cameras. T-test and effect size statistics established significant differences in the power phase (0-180°) of the crank cycle for knee abduction, knee extension and hip adduction between the two groups. Increase in hip and knee frontal plane motion indicated altered pedalling technique for recreational cyclists.

KEY WORDS: biomechanics, 3D analysis, pedalling, technique.

INTRODUCTION: The popularity of cycling as a recreational and sportive activity is still increasing in the Czech Republic. Besides many positive aspects on physical and mental health, approximately 85% of recreational cyclist suffer from overuse injury at least once during their cycling career (Wilber, Holland, Madison, & Loy, 1995), with the knee (42%) being the most affect (Schwellnus & Derman, 2005). Clarsen, Krosshaug, & Bahr (2010) stated that in cycling, the knee joint is the most predisposed to chronic injuries due to relatively large joint range of motion and high frequency of repetition rates. Previous studies focused on sagittal plane kinematics and kinetics of the hip, knee and ankle investigating e.g. effects of saddle height (e.g Tamborindeguy & Bini, 2011), code of specialisation (cyclists vs. triathletes) (Bini, Hume, & Kilding, 2014), and chainring design (e.g. Strutzenberger et al., 2014). In sagittal plane pedalling motion is linked to pedalling intensity (Bini, Senger, Lanferdini, & Lopes, 2012; Peveler, Shew, Johnson, & Palmer, 2012), but frontal and transversal kinematics were only under limited focus. Preliminary research identified frontal plane motion as useful parameter to distinguish between cyclists experiencing pain or no pain: Bailey, Maillardet, & Messenger (2003) investigated differences in hip, knee and ankle frontal plane kinematics between cyclists with anterior knee pain and pain-free cyclists. The authors demonstrated that cyclists with anterior knee pain exhibited larger medial projection of their knees compare to pain-free cyclists. However, it yet remains unknown, if training status can alter the sagittal and frontal plane pedalling motion of healthy athletes and whether the sagittal and frontal lower limb kinematics alter due to work load (Bini et al., 2016) and cadence.

Therefore, the aim of the current study was to compare sagittal and frontal hip, knee and ankle joint kinematics between competitive and recreational road cyclists across different workloads and pedalling cadences. The results of the current study could help to cyclists, coaches and bike fitters to assess if body motion is influenced by different training volume, workload and cadence. Overall purpose of the current research to provide information, which is essential for the interpretation of sagittal and frontal plane cycling kinematics and which will find application for training recommendations.

METHODS:

Participant & Protocol: Five competitive (training volume 16400±3600 km/year, age 28.0±4.9 years, height 180.0±4.9 cm and weight 74.0±2.8 kg) and five recreational (training volume 3800±1500 km/year, age 27.0±5.6 years, height 182.0±4.9 cm and weight 75.0±4.0

kg) healthy male road cyclists from the Czech Republic participated in this study. All procedures were verbally explained to each athlete and informed consent was obtained in accordance with the guidelines of the Ethics and Research Committee of University of Ostrava. A road race bicycle with a crank arm length of 175 mm was individually fitted and mounted on an indoor ergo-trainer (Elite, Fontaniva, Italy) and instrumented back wheelset (PowerTap G3 Hub, PowerTap, Madison, USA) for measurement workload and cadence (Figure 1). Bicycle was configured to elicit 30° of knee flexion angle using a goniometer with 1° of resolution while cyclists sustained in a static pose at 180° of crank cycle (De Vey Mestdagh, 1998). After a 5 minutes' warm-up (150 W, individual cadence), four cycling conditions were performed in random order. In terms of high ecological validity, the conditions were selected in order to cover various cadences typically used during competition or training and based on athletes' feedback as: 200 W, 95 rpm (plane); 200 W, 85 rpm (slight hill); 230 W, 75 rpm (medium hill); and 230 W, 65 rpm (steep hill). Participants cycled for 1 minute at each of the four conditions and the last 20 seconds of each condition were recorded and used for further data analysis. A rest of 2 min (individual speed) was ensured between the trials to reduce fatigue effects.

Figure 1: Experimental set-up.

Data Collection & Analysis: A motion-capture system consisting of nine infrared cameras (Qualisys, Sweden, 240 Hz) was used to collect three dimensional kinematic data. Retroreflective markers and rigid clusters were attached to the athletes' lower limb, pelvis and trunk (C-motion, Rockville, MD, USA). Fifteen consecutive crank cycles in each condition were used for further analysis. Crank cycle was determined using 5th metatarsal vertical coordinates to determine the most vertical position (0°) as beginning of each cycle. Raw data were processed using the Visual 3D software (C-motion, Rockville, MD, USA). Kinematic variables included hip, knee and ankle sagittal and frontal joint angles. These variables were calculated using a XYZ order of rotation. The coordinate data were low-pass filtered using a fourth-order Butterworth filter with a 12 Hz cut-off frequency. All analysis was focus on peak mean hip, knee and ankle joint kinematics during the power phase of the crank cycle (0–180°) (Bini et al., 2016). Means and standard deviations (M±SD) were calculated for all measured variables. Statistical significance in between groups in each condition was quantified using paired t-tests with alpha set to 0.05. Effect sizes (ES) were calculated and interpreted as <0.2 trivial; 0.21-0.5 small; 0.51-0.8 medium and >0.8 large (Cohen, 1988). The effect of >0.8 was considered to be practically significant. Statistical analyses were performed using IBM SPSS Statistics 20.

RESULTS: No significant differences between recreational and competitive cyclists were found for age, height and weight. Group means and standard deviations for hip, knee and ankle joint kinematics taken during the power phase of the crank cycle (0–180°) for recreational and competitive cyclists across four conditions are displayed in Table 1. As for hip joint kinematics practically significant differences (ES>0.8) were found for peak hip abduction in all conditions (Table 1). No significant differences were found for peak hip extension. Practically significant differences (ES>0.8) were found between recreational and competitive cyclists in peak knee abduction and peak knee extension (Table 1). No significant differences were found for peak ankle dorsiflexion and peak ankle eversion.

Table 1
Group mean (± standard deviations) ranges of motion for joint angles taken during the power phase (0°-180°) of the crank cycle for recreational (Rec) and competitive (Com) cyclists.

Variable	Group	Plane	Slight hill	Medium hill	Steep hill
Peak Hip Extension (°)	Com	94.57±9.06	96.66±8.74	95.78±10.57	96.00±9.06
	Rec	95.96±7.18	95.21±6.70	98.30±6.70	97.57±5.42
Peak Hip Abduction (°)	Com	4.44±1.61[b]	3.95±1.45[b]	4.81±1.95[b]	4.57±1.66[b]
	Rec	1.98±3.14[b]	2.33±1.98[b]	1.13±2.49[b]	1.26±2.01[b]
Peak Knee Extension (°)	Com	48.86±7.35[b]	48.43±6.78[b]	47.91±7.56[b]	47.86±7.16[a,b]
	Rec	41.49±8.74[b]	39.50±7.21[b]	38.53±6.86[b]	37.00±5.56[a,b]
Peak Knee Abduction (°)	Com	1.48±2.86[b]	2.60±3.95[b]	1.95±2.60[b]	2.99±3.35
	Rec	5.57±5.93[b]	6.20±4.85[b]	5.70±5.83[b]	5.67±5.73
Peak Ankle Dorsiflexion (°)	Com	54.60±7.86	57.61±8.20	55.53±8.71	56.53±8.90
	Rec	56.89±2.93	56.98±4.06	59.11±3.95	58.45±8.30
Peak Ankle Eversion (°)	Com	7.05±4.87	6.68±4.56	7.84±5.64	7.55±5.22
	Rec	10.22±5.69	9.64±5.21	11.57±5.65	11.50±6.58

Notes: [a]statistically significant ($p<0.05$); [b]practically significant (ES>0.8)

DISCUSSION: The aim of the current study was to compare hip, knee and ankle joint kinematics between competitive and recreational road cyclists across different workloads and pedalling cadences. The main findings from our study were that recreational cyclists presented increased peak knee abduction (differences between groups ranged from 2.7° to 4.1° in the four conditions), knee extension (differences 7.4°–10.9°) and hip adduction (differences 1.6°–3.7°) than competitive cyclists. In the current study significant increase in peak knee extension was observed for recreational cyclists in all conditions (Table 1) with large effect sizes (ES=0.91, plane; ES=1.11, slight hill; ES=1.30, medium hill; and ES=1.70 steep hill, p=0.035). These changes could be probably due to pelvis movement as recreational cyclist move backward on the saddle due to harder pedalling to produce more force. However, more detailed analysis of pelvis movement is needed further. Another explanation could be due to ankle movement. Table 1 shows slightly increase in ankle dorsiflexion for recreational cyclists. This indicates that recreational cyclists might not have enough strength to keep the ankle position, and thus dorsiflex the ankle in the pushing phase of the crank cycle. These findings are similar to those previously presented by Bailey et al. (2003) for group of cyclists with history of knee pain. Moreover, increases in the knee extension suggest the need for higher knee extensor muscles strength for recreational cyclists to complete this motor task.

In various sports, including running (Foch et al., 2015), landing (Hewett et al., 2005) and cycling (Bailey et al., 2003), injury mechanism has been associated with segment and joint motion out of the sagittal plane. In the current study recreational cyclists showed increase in knee abduction from moderate (ES=0.57, steep hill) to large (ES=0.88, plane; ES=0.81, slight hill; and ES=0.83, medium hill) effect sizes. Moreover, for hip adduction large effect sizes (ES=0.99, plane; ES=0.93, slight hill; ES=1.68, medium hill; and ES=1.80, steep hill) were found in all four conditions (Table 1). From an injury perspective the frontal plane kinematics of the recreational cyclists are in concurrence with the pain group presented by Bailey et al. (2003). In this paper authors stated that greater knee abduction and hip adduction was linked to cyclist with history of anterior knee pain. We speculate that increase in knee abduction and hip adduction could be due to decrease in abductor muscles strength, accompanied with decrease in medial quadriceps strength for recreational cyclists. Therefore, it further needs to be clarified, whether significant differences in power phase of

crank cycle for knee abduction, knee extension and hip abduction may indicate harmful pedalling technique for recreational cyclists.
Conclusions from this study must be considered with the small sample size in mind, which reduces the wider application of these results. However, these initial findings provide a foundation to investigate this area further, with different performance levels, gender, age, and cyclists with history of pain or injury to examine other factors that may influence the occurrence of injury and to improve performance.

CONCLUSION: In conclusions, significant differences in power phase of crank cycle were found for knee abduction, knee extension and hip abduction. The recreational cyclists demonstrated higher knee abduction, knee flexion and hip adduction in pain free conditions. Moreover, the differences in knee extension seem to be more prevalent in the more difficult conditions (plane vs. hills) for recreational cyclists. The implications of the current study could help cyclists and coaches to assess, if body motion is influenced by different training volume, workload and cadence.

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