ROAD BIKE DAMPING: COMFORT OR PERFORMANCE RELATED?

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The aim of this study was to determine if a road bike specific damping system increases short term performance. Muscular activation of the triceps surae and quadriceps femoris, oxygen consumption, heartrate and maximum power output of thirty male, trained cyclists were recorded. The participants performed on a damped and non-damped road racing bike six-minute steady state and four-minute all-out tests with and without vibration. Vibration significantly increased the mean activation of the triceps surae and significantly increased oxygen uptake and heartrate. Damping had no impact on muscular activation, energy requirements and cardiopulmonary response. It is therefore concluded, that cycling specific vibration affects the musculoskeletal system and slightly increases total energy demand. Damping contributes to upper body comfort but does not influence short term performance directly.

KEYWORDS: cycling, vibration, comfort, performance, muscular activation, oxygen consumption

INTRODUCTION: Vibrations, such as those caused by cobblestones or bumpy roads, are not only responsible for discomfort in cycling, but are also considered relevant to injury (Schwellnus & Derman, 2005) and may influence neurophysiological performance (Filingeri, Jemni, Bianco, Zeinstra, & Jimenez, 2012; Sperlich, Kleinoeder, Quarz, Linville, & Haegele, 2009). A new class of comfort-oriented racing bikes aims at damping the accelerations transmitted to the rider through less rigid seat posts or damping elements between the frame and stem. The initiation and transmission of vibration are complex due to multiple contact points such as handlebars, pedals and saddle and dynamically changing load conditions within the crank cycle. There is also a suggestion that the activation of different muscle groups depends on the type of vibration stimulus (Munera, Bertucci, Duc, & Chiementin, 2018). Different vibration characteristics may therefore also be a cause of not entirely homogenous results regarding muscular activation, (Munera et al. 2018; Srinivasan & Balasubramanian, 2007), cardiopulmonary demands (Filingeri et al., 2012; Munera et al., 2018; Sperlich et al. 2009) and muscular metabolism (Filingeri et al.2012; Mester, Spitzenfeil, Schwarzer & Seifriz, 1999). Damped endurance-bikes effectively reduce the resulting accelerations on the upper body and arms compared to a classic road bike and thus contribute to riding comfort. However, the accelerations transmitted to the lower extremities did not significantly differ (Viellehner & Potthast, 2018). From a performance perspective, it is decisive to what extent propulsion-generating muscle groups of the lower extremities are possibly affected by vibration and damping. Along with a reduced load on the stabilizing upper extremities, this might reflect in systemic criteria such as metabolic costs and stress on the cardiovascular system.
The aim of this study was, to determine whether vibration in cycling causes additional expenditure on a muscular level and to what extent damping helps to lower the possibly increased metabolic energy requirements or the stress on the cardiovascular system.

METHODS: For the identification of vibration and damping effects, thirty trained amateur cyclists (mass 75.9 ± 8.9 kg, body height 1.82 ± 0.05 m, Vo2max 63 ± 6.8 ml/min/kg) performed laboratory-based test rides on a damped (Specialized Roubaix Comp, 2017) and nondamped (Specialized Tarmac SL5 Expert, 2017) racing bike with and without vibration. The damped bike design includes a 20 mm damping unit in between frame and stem (Futureshock, Specialized USA) and a flexible seat post with reduced vertical and anterior-posterior stiffness. Two vibration plates (Netter Vibration, VTE 5/5 - 2NEG 50300) were used to apply cobblestone specific vibrations directly into the front- (44 Hz, 4.1 mm amplitude) and rear-dropout (38 Hz, 3.5 mm amplitude). For a more detailed description, please refer to Viellehner & Potthast

(2018). The test design included an initial metabolic testing block with individually scaled power level (60% of Vo2max), subdivided into six-minute steady state sections with and without vibration application and a four-minute maximum effort time trial with vibration. To avoid familiarization effects at the time trial, ‘damped’ and ‘nondamped’ testing days were randomized. Due to the increasing load protocol, the order of the test conditions within the metabolic test section was not randomized. Oxygen consumption was sampled breath by breath and averaged over the last three minutes of every test condition (nSpire, Zan600 USB, Germany). Heart rate (SRM 5th Gen, SRM, Jülich, GER) is reported as the mean value of the same time intervals. A crank-based power meter (SRM 5th Gen, SRM, Jülich, GER) measured power (221 ± 18 W) and helped to control the specified cadence of 80 - 90 rpm. For the prevention of fatigue effects, the motion analysis testing block followed after a one-hour passive recovery break and replicated the previous test conditions shortened to two minutes. Motion analysis included EMG (Myon, Schwarzenberg, CH, 1000 Hz, Butterworth 5-500 Hz bandpass, 2nd order, recursive), accelerometry (Viellehner & Potthast 2018) and kinematic data (14 infrared cameras, ViconTM Oxford, UK; MX F40, 200 Hz). The order of vib and novib conditions within each power level was randomized. The muscular activation for gastrocnemius medialis, soleus, vastus medialis and rectus femoris is reported as the signal envelopes (Butterworth 15 Hz lowpass, 2nd order, recursive) mean value over 15 consecutive cycles, normalized to the baseline NoVib x NoDamping condition. The starting point of the crank cycle was defined as the highest point of the pedal axis during one revolution.
A two-way repeated-measures ANOVA identified the effects of vibration and bike damping. Descriptive and inferential statistics were conducted using Matlab (Matlab R2018B, The MathWorks, USA).

RESULTS: Vibration significantly increased the mean activation of the gastrocnemius medialis about 14% and soleus about 30% for both bike types compared to the Novib condition, as visualized in figure 1. Opposite to this, damping during vibration had no significant impact on the calf muscles. M. vastus medialis and m. rectus femoris showed no response to vibration or damping. The mean heartrate comparably increased during vibration by 5% for the damped and 6% for the nondamped bike. The average oxygen uptake increased during vibration significantly for both bikes by 2%. The average power output of the four minutes time trials of 4.55 ± 0.69 W/kg and 4.48 ± 0.71 W/kg respectively, did not differ significantly between the damped and undamped bike. Discrete values are presented in Table 1.

Table 1: Muscular activation, cardiopulmonary response and four minute time trial power for the damped and non-damped bike. * indicates significant Vib - NoVib difference ($p < 0.05$)

	NoDamping		Damping	
	NoVib	Vib	NoVib	Vib
Mean muscular activation				
m. GastrocMed [% baseline]	0.31 ± 0.06	0.36 ± 0.07*	0.30 ± 0.06	0.35 ± 0.07*
m. Soleus [% baseline]	0.33 ± 0.05	0.47 ± 0.21*	0.32 ± 0.04	0.48 ± 0.14*
m.VastMed [% baseline]	0.34 ± 0.05	0.34 ± 0.05	0.35 ± 0.04	0.37 ± 0.06
m. RecFem [% baseline]	0.41 ± 0.08	0.46 ± 0.18	0.41 ± 0.08	0.44 ± 0.13
Cardiopulmonary				
Heartrate [bpm]	150 ± 16	161 ± 16*	153 ± 16	161 ± 15*
VO_2 [ml/min/kg]	41 ± 5	42 ± 4.8*	42 ± 6	43 ± 6.1*
Mechanical Power				
Time Trial Power [W/kg]		4.48 ± 0.71		4.55 ± 0.69

DISCUSSION: Cycling specific vibration affects the musculoskeletal system and total energy demand. A slightly increased oxygen uptake in combination with an increased heart rate indicates higher requirements for the metabolic and cardiopulmonary system. However, the

mechanical equivalent of the vibration related additional oxygen demand is very low (Glass & Brown, 2007). Munera and colleagues (2018) proposed a muscle-specific sensitivity for different vibration stimuli during cycling. For this reason, the different vibration characteristics used in the test designs might provide an explanation why they found no vibration effect regarding oxygen uptake, while other test designs with a better comparable vibration stimulus to the present work support the results (Filingeri et al., 2012; Sperlich et al., 2009).
The vibration-induced effects on muscular activation can be differentiated by increased activation of the muscles related to the ankle joint and a consistent level of activation for the more proximal muscles related to the knee. Concerning the functional participation of individual

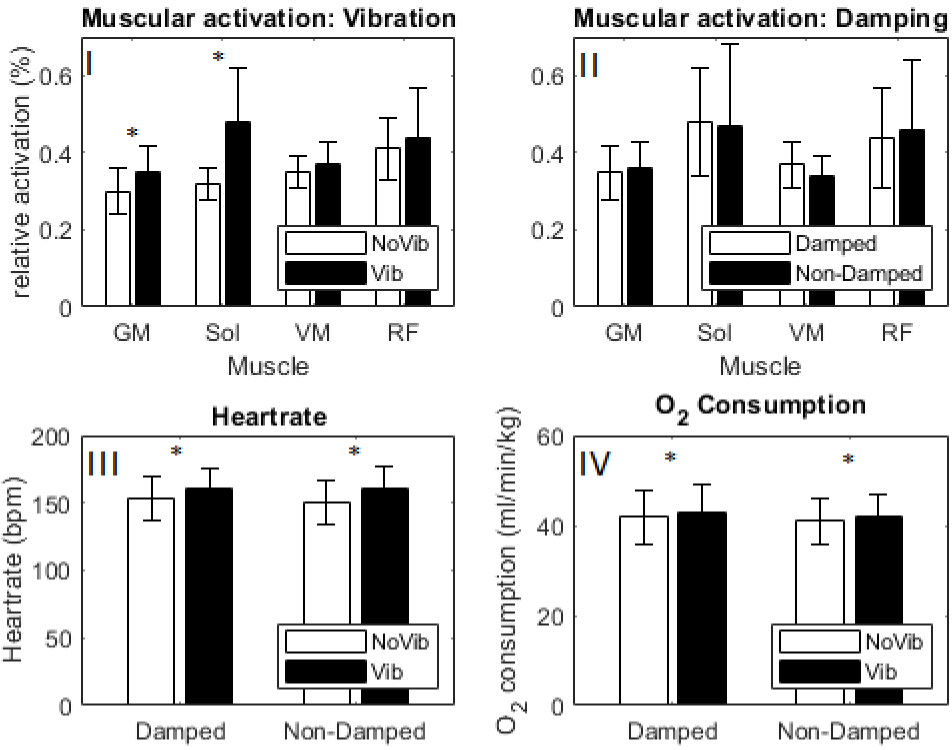

Figure 1: Top line: Visualization of the effect of vibration (I) and damping (II) on mean relative muscular activation for gastrocnemius medialis (GM), soleus (Sol), vastus medialis (VM) and rectus femoris (RF). Bottom Line: Visualization of the effect of vibration and damping on heartrate (III) and oxygen consumption (IV). * indicates significant Vib - NoVib difference ($p < 0.05$)

muscle groups for power generation, knee and hip extensors mainly provide the energy for the lower and upper leg segments, which is transferred through a stiffened ankle joint to the crank (Zajac, Neptune & Kautz, 2002). Furthermore, the ankle joint generates only a small amount of the propulsion compared to the hip and knee joint (Mornieux, Guenette, Sheel & Anderson, 2007). For this reason, the increased activation of the calf muscles may primarily contribute through an adapted ankle joint stiffness to damping in order to enable a more advantageous mechanical framework for the proximal muscle groups. This mechanism is supported by the finding of unchanged activation levels for the vastus medialis and rectus femoris, which indicates a small impact of vibration on the main propulsive muscles. For this reason the marginal increased energy requirement is probably related to additional tasks such as damping in the ankle joint or upper extremities.
Damping showed no effect on muscular activation of the lower extremities. Also, heart rate and oxygen uptake during vibration did not change significantly for the damped compared to the undamped bike. Accordingly, the average performance of the four-minute time trials for both bikes did not differ significantly. This supports previous findings, which reported for

damped bikes reduced accelerations at the upper body, but comparable acceleration transmission to the main propulsive muscle groups compared to nondamped bikes (Viellehner & Potthast, 2018). As a result, damping is mainly linked to comfort, while it does not enhance or compromise short term performance.
Taking under consideration the main propulsive muscle groups low sensitivity to vibration and only marginal increased energy requirements, vibration does not directly interfere with power production. Out of a short-term performance focused perspective the necessity for damping is low. In this first stage, the approach focusses on maximum power output rather than on endurance and fatigue aspects. It should be mentioned that at racing distances about 200 km, additional comfort and fatigue reduction can play a decisive role. In order to make more precise statements on a functional level, the inclusion of more muscle groups in the EMG analyses, as well as an inverse dynamic approach for detailed information on joint-specific functionality should be considered.

CONCLUSION: Vibration in cycling increases the demands on the musculoskeletal system, nevertheless the impact on overall performance is small. Muscular activation, energy requirements, and cardiopulmonary response do not differ for the damped and nondamped bike. Therefore, bicycle damping does not influence short term performance. Hardly affected main propulsive muscles and marginal additional energy demand during vibration suggest that the primary task of damping in roadcycling is to provide comfort over long periods of time and not to act as a short term performance enhancer. The results presented are applicable for example to a typical two- to four-minute attacking situation on cobbles in bicycle racing. These results may help athletes and coaches select bikes for racing on cobbled roads or spring classics terrain.

REFERENCES

Filingeri, D., Jemni, M., Bianco, A., Zeinstra, E., & Jimenez, A. (2012). The effects of vibration during maximal graded cycling exercise: A pilot study, *Journal of Sports Science and Medicine*, 11, 423-429.

Glass, S., Dwyer, G. B., & American College of Sports Medicine. (2007). ACSM'S metabolic calculations handbook. Philadelphia: Lippincott Williams & Wilkins.

Mester, J., Spitzenfeil, P., Schwarzer, J., & Seifriz, F. (1999). Biological reaction to vibration-Implications for sport. *Journal of Science and Medicin in Sport/Sports Medicine Australia*, 2(3), 211–226.

Mornieux, G., Guenette, J., Sheel, A. & Sanderson, D. (2007). Influence of cadence, power output and hypoxia on the joint moment distribution during cycling. *European Journal of Applied Physiology,* 1(102), 11-18.

Munera, M., Bertucci, W., Duc, S., & Chiementin, X. (2018). Analysis of muscular activity and dynamic response of the lower limb adding vibration to cycling. *Journal of Sports Sciences*, 36(13), 1465–1475.

Schwellnus, M., & Derman, E. (2005). Common injuries in cycling: Prevention, diagnosis and management. *South African Family Practice*, 47(7), 14–19.

Sperlich, B., Kleinoeder, H., Marées, M. D., Quarz, D., Linville, J., & Haegle, M. (2009). Physiological and perceptual responses of adding vibration to cycling, *Journal of Exercise Physiology online*, 12 (2), 40-46.

Srinivasan, J., & Balasubramanian, V. (2007). Low back pain and muscle fatigue due to road cycling—An sEMG study. *Journal of Bodywork and Movement Therapies*, 11(3), 260-266.

Viellehner, J. & Potthast, W. (2018). Acceleration transmitted to the human body during cycling: Effect of a road bike damping system. ISBS - *Conference Proceedings Archive: 36 International Society of Biomechanics in Sports* (2018).

Zajac, F., Neptune, R. & Kautz, S. (2002). Biomechanics and muscle coordination of human walking: Part I: Introduction to concepts, power transfer, dynamics and simulations. *Gait & Posture*, 16(3), 215-232.

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