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Acute whole-body vibration increases reciprocal inhibition

Ramona Ritzmann, Anne Krause*, Kathrin Freyler, Albert Gollhofer

Department of Sports and Sports Science, University of Freiburg, Schwarzwaldstraße 175, 79117 Freiburg, Germany

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ABSTRACT

Based on previous evidence that whole-body vibration (WBV) affects pathways involved in disynaptic reciprocal inhibition (*DRI*), the present hypothesis-driven experiment aimed to assess the acute effects of WBV on *DRI* and co-contraction. *DRI* from ankle dorsiflexors to plantar flexors was investigated during submaximal dorsiflexion before and after 1 min of WBV. With electromyography, musculus soleus (SOL) H-reflex depression following a conditioning stimulation of the peroneal nerve (1.1x motor threshold for the musculus tibialis anterior, TA) was assessed and co-contraction was calculated. After WBV, *DRI* was significantly increased (+4%, $p < 0.05$). SOL (−13%, $p < 0.05$) and TA (−6%, $p < 0.05$) activities were significantly reduced; co-contraction tended to be diminished (−8%, $p = 0.05$). Dorsiflexion torque remained unchanged. After WBV, *DRI* increased during submaximal isometric contraction in healthy subjects. The simultaneous SOL relaxation and TA contraction indicate that a more economic movement execution is of functional significance for WBV application in clinical and athletic treatment.

1. Introduction

In the last decade, increasing emphasis has been placed on neuromuscular training to improve motor control during human movement. In this context, whole-body vibration (WBV), the use of high-frequency mechanical oscillations to stimulate skeletal muscles, has been brought to the forefront (Rittweger, 2010). Numerous studies have demonstrated improved performance in response to WBV, including increases in strength (Delecluse, Roelants, & Verschueren, 2003; Roelants, Delecluse, & Verschueren, 2004; Torvinen et al., 2002), power (Rees, Murphy, & Watsford, 2008; Roelants et al., 2004), and rate of force development (Cochrane, Stannard, Firth, & Rittweger, 2010) in isometric and dynamic muscle actions. Furthermore, experiments have shown that WBV acts on neuromuscular coupling and improves motor coordination (Cochrane, 2010; Ness & Field-Fote, 2009; Stark, Nikopoulou-Smyrni, Stabrey, Semler, & Schoenau, 2010). Although it has been argued that neural enhancement at the spinal level may underlie such WBV-induced improvements, the mechanisms and neuromuscular potentiation effects have received little attention (Cochrane, 2011).

Neurophysiological research has highlighted that accurate and effective movement execution requires remarkably precise coordination of the involved agonistic and antagonistic muscles. Neuronal circuitries in the spinal cord are pivotal to ensuring synergistic and antagonistic muscle coordination (Nielsen, 2004). One well-established mechanism involves the disynaptic reciprocal inhibitory (*DRI*, Fig. 1A) pathway (Crone, Nielsen, Petersen, Ballegaard, & Hultborn, 1994). Reciprocal inhibition is defined as the inhibition of antagonistic alpha motor neurons evoked through contraction of the agonistic muscle (Crone, 1993) under the control of supraspinal centers (Pierrot-Desseilligny & Burke, 2012). The Ia muscle spindle afferents innervate the homonymous alpha motor neuron, which causes the muscle to contract (Crone, 1993). Simultaneously, an inhibitory interneuron is innervated at the alpha motor neuron, which synapses onto the antagonistic muscles (Pierrot-Desseilligny & Burke, 2012). The activation of this inhibitory

* Corresponding author at: Department of Sports and Sports Science, University of Freiburg, Schwarzwaldstraße 175, 79117 Freiburg, Germany.
E-mail address: a.krause@dshs-koeln.de (A. Krause).

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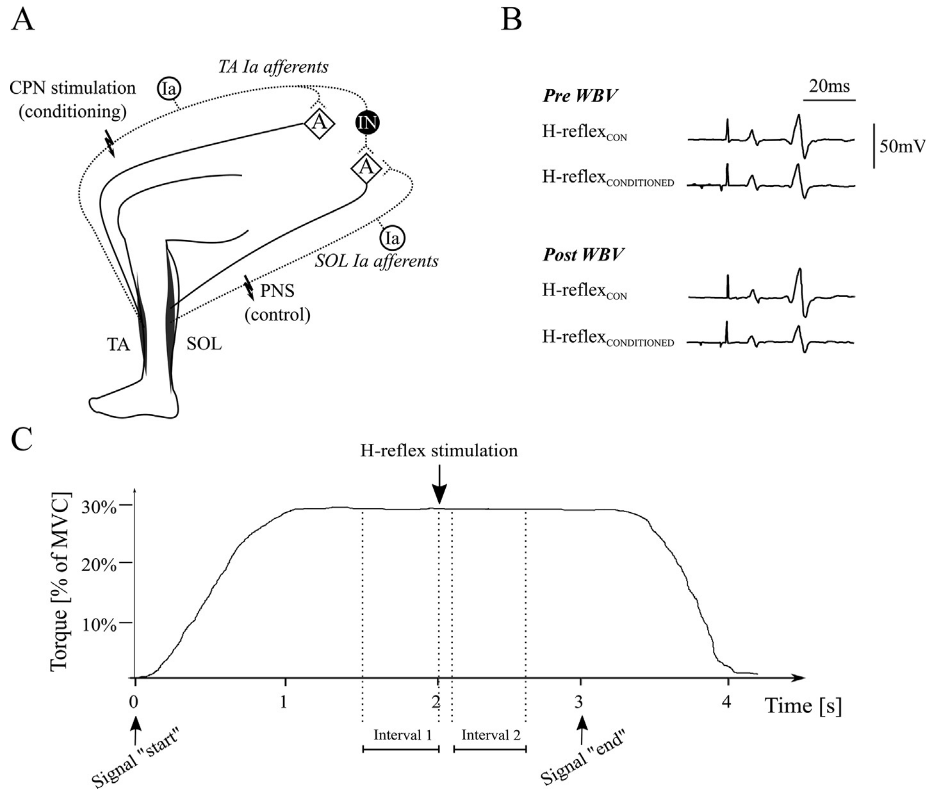

Fig. 1. Study methodology and setting. ***A*** illustrates that disynaptic reciprocal inhibition was assessed by peripheral nerve (PNS) and common peroneal nerve (CPN) stimulation at different conditioning-test intervals, leading to a conditioning of the H-reflex. ***B*** shows an example of an unconditioned (H-reflex$_{CON}$) and conditioned (H-reflex$_{CONDITIONED}$) H-reflex during submaximal dorsiflexion before and after WBV. ***C*** illustrates a submaximal dorsiflexion torque of a representative subject. Electromyographic activity of plantar flexors and dorsiflexors was recorded prior to H-reflex stimulation (−500–0 ms, Interval 1). Dorsiflexion torque was assessed prior to (Interval 1) and following (100–600 ms, Interval 2) H-reflex stimulation.

interneuron prevents excitation of the antagonistic alpha motor neuron pool and diminishes antagonistic muscle contraction. Without *DRI*, both muscle groups would contract simultaneously (Crone & Nielsen, 1994), leading to poor intermuscular coordination.

In the context of functional neuromechanics, reciprocal inhibition is a ubiquitous phenomenon which is considered to be of major relevance in movement control (Crone, 1993). Increased reciprocal inhibition in appropriate muscle groups has been shown to increase strength and flexibility (Blazevich et al., 2012; Geertsen, Lundbye-Jensen, & Nielsen, 2008; Nielsen & Kagamihara, 1992), improve performance in fine motor tasks that require a high degree of accuracy (Floeter, Danielian, & Kim, 2013), prevent injury (Shrier, 2007), and diminish muscle spasms in patients suffering from neurological disorders (Morita, Crone, Christenhuis, Petersen, & Nielsen, 2001). Beyond the functional aspects, reciprocal inhibition is a key mechanism by which to regulate the level of antagonistic co-contraction (Geertsen et al., 2008); thus, agonistic muscle contraction (initiating a movement) reduces the tension in the antagonistic muscle (opposing the movement), which simultaneously relaxes (Crone & Nielsen, 1994). As a consequence, motor coordination becomes more efficient, accurate, and economical (Floeter et al., 2013; Lavoie, Devanne, & Capaday, 1997; Nielsen & Kagamihara, 1992).

Anecdotal evidence indicates potential modulation of *DRI* by WBV; however, no firm evidence regarding the mechanism exists. Nevertheless, experiments have indicated a persistent vibration-induced modulation at the spinal and supraspinal level. Reduced Ia afferent transmission (Krause, Gollhofer, Freyler, Jablonka, & Ritzmann, 2016; Sayenko, Masani, Alizadeh-Meghrazi, Popovic, & Craven, 2010) occurs concomitantly with facilitation of supraspinal pathways projecting onto the alpha motoneuron pool (Krause et al., 2016; Mileva, Bowtell, & Kossev, 2009). Particularly notable effects have been demonstrated for WBV exercises executed at a frequency of 30 Hz (Krause et al., 2016) and an amplitude of 4 mm (Ritzmann, Kramer, Gollhofer, & Taube, 2013). Furthermore, local vibration applied to the muscle belly indicates increased corticospinal excitability in the vibrated muscle (Rosenkranz & Rothwell, 2003), while the non-vibrated antagonistic muscle is simultaneously suppressed (Liepert & Binder, 2010; Rosenkranz & Rothwell, 2003). Cody, Henley, Parker, and Turner (1998) found an increase in *DRI* during local vibration treatment applied to hand musculature. None of these studies, however, applied H-reflex conditioning techniques to clearly distinguish the contribution of *DRI* to WBV-induced benefits in movement control (Crone et al., 1994; Geertsen et al., 2008).

Taken together, valuable preliminary findings and limited current knowledge persuaded us to carry out an experiment aimed at evaluating the immediate effect of WBV on *DRI* and antagonistic co-contraction of muscles encompassing the ankle joint (Pel et al.,