Human Movement Science 55 (2017) 221–228

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

Local vibration inhibits H-reflex but does not compromise manual dexterity and does not increase tremor

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ARTICLE INFO

Keywords:
Vibration
H-reflex
Tremor
Manual dexterity
Steadiness

ABSTRACT

The present work aimed at investigating the effects of local vibration on upper limb postural and kinetic tremor, on manual dexterity and on spinal reflex excitability. Previous studies have demonstrated a decrease in spinal reflex excitability and in force fluctuations in the lower limb but an increase in force fluctuation in the upper limbs. As hand steadiness is of vital importance in many daily-based tasks, and local vibration may also be applied in movement disorders, we decided to further explore this phenomenon. Ten healthy volunteers (26 ± 3 years) were tested for H reflex, postural and kinetic tremor and manual dexterity through a Purdue test. EMG was recorded from flexor carpi radialis (FCR) and extensor digitorum communis (EDC). Measurements were repeated at baseline, after a control period during which no vibration was delivered and after vibration. Intervention consisted in holding for two minutes a vibrating handle (frequency 75 Hz, displacement ~7 mm), control consisted in holding for two minutes the same handle powered off. Reflex excitability decreased after vibration whilst postural tremor and manual dexterity were not affected. Peak kinetic tremor frequency increased from baseline to control measurements ($P = 0.002$). Co-activation EDC/FCR increased from control to vibration ($P = 0.021$). These results show that two minutes local vibration lead to a decrease in spinal excitability, did not compromise manual dexterity and did not increase tremor; however, in contrast with expectations, tremor did not decrease. It is suggested that vibration activated several mechanisms with opposite effects, which resulted in a neutral outcome on postural and kinetic tremor.

1. Introduction

Any static or dynamic muscle contraction shows involuntary irregularities, which, if they tend towards rhythmical oscillations are referred to as physiological tremor (Marshall & Walsh, 1956). To date a number of both mechanical and neural mechanisms have been listed as elements contributing to this complex phenomenon (for review (McAuley & Marsden, 2000)). Among the neural mechanisms are reflex loop resonances (Durbaba, Taylor, Manu, & Buonajuti, 2005; Lippold, 1970) and motor units discharge properties (Elble & Randall, 1976; Taylor, Christou, & Enoka, 2003). Both of these are related to Ia afferent activity. For this reason it could be argued that muscle vibration, as it depresses Ia afferents (Burke, Hagbarth, Löfstedt, & Wallin, 1976) with subsequent effects on reflex excitability (Fry & Folland, 2014; Ritzmann, Kramer, Gollhofer, & Taube, 2013) and on motor unit recruitment (Pollock, Woledge,

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http://dx.doi.org/10.1016/j.humov.2017.08.018
Received 23 March 2017; Received in revised form 21 August 2017; Accepted 21 August 2017
Available online 01 September 2017
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Martin, & Newham, 2012; Romaiguère, Vedel, & Pagni, 1993), could also influence force fluctuations during muscle contractions.

Indeed, prolonged muscle vibration was demonstrated to reduce the normal increase in tremor during sustained fatiguing isometric plantar flexions at 30% of maximal voluntary contraction (MVC) (Cresswell & Löscher, 2000) and a decrease in the standard deviation (SD) of force during isometric plantar flexions performed at 2.5 and 10% MVC (Yoshitake, Shinohara, Kouzaki, & Fukunaga, 2004). By applying the same vibration though, Saito, Ando, and Akima (2016) reported neither changes in coefficient of variation (CoV) of the force nor changes in the power spectra analysis within any frequency band, during isometric knee extensions at 2.5, 10 and 30% MVC. Opposite results were obtained during isometric elbow flexions at 15% MVC following five seconds of vibration (+40% in CoV (Harwood, Cornett, Edwards, Brown, & Jakobi, 2014)), and during isometric contraction of the first dorsal interosseous at ~5% MVC following 30 minutes of tendon vibration (+21% SD of force signal (Shinohara, Moritz, Pascoe, & Enoka, 2005)). Specificity of the muscle group tested, in terms of muscle spindle density and sensitivity, was proposed as one possible explanation for the diverse findings (Saito et al., 2016; Shinohara et al., 2005). This justification is legitimate and further supported by the evidence that muscle spindle afferents inputs are unevenly distributed among motor units (MUs) of synergistic muscles and even among MUs of the homonymous muscle (Hamm, Koehler, Stuart, & Vanden Noven, 1985; Lucas, Cope, & Binder, 1984). Nevertheless, the 29% increase in force steadiness reported by Yoshitake and colleagues during plantar flexion (Yoshitake et al., 2004) is a remarkable result worth to be further investigated on upper body muscles.

Shinohara and colleagues (2005) reported a 21% increase in force fluctuations during first dorsal interosseous contractions as result of 30 minutes of vibration and hypothesised that this outcome could be attributed to the prolonged activation of the tonic vibration reflex (TVR). Activation of the TVR was suggested to induce a failure in the excitation-contraction coupling (Martin & Park, 1997) due to the onset of vibration-induced muscle fatigue (Park & Martin, 1993). In support of this argument, Mottram, Maluf, Stephenson, Anderson, and Enoka (2006) showed that the time to task failure during a sustained fatiguing elbow flexion contraction was shorter when vibration at supra threshold TVR was applied during the effort compared to when the vibration was sub threshold or was not applied. Accordingly, Shinohara and colleagues (2005) described the reduced maximal force capacity of the muscle after vibration as something similar to what is observed as consequence of muscular fatigue produced by prolonged low intensity effort (Kouzaki, Shinohara, Masani, & Fukunaga, 2004). Further similarities between the effects of fatigue and vibration can also be found in relation to MUs recruitment. In this regard, it was reported an increased recruitment threshold of lower threshold MUs and a decreased recruitment threshold of higher threshold MUs both following vibration (Pollock et al., 2012) and during muscle fatigue (Carpentier, Duchateau, & Hainaut, 2001). Taking together these evidences, it seems reasonable to embrace Shinohara and colleagues' (2005) hypothesis that the decreased steadiness following vibration could be attributed to muscle fatigue induced by prolonged activation of the TVR. Other elements acknowledged by the authors (Shinohara et al., 2005) as potential limitations include the location of the vibration and the lack of H reflex measurements.

The purpose of the present work was therefore to further investigate the effects of vibration on hand steadiness trying to overcome some of the methodological limitations highlighted by Shinohara and colleagues (2005). Firstly, shorter vibration time was used in order to avoid a failure in the excitation-contraction coupling. Second, postural and kinetic tasks were measured instead of isometric contractions. In fact, muscle spindles discharge frequency decays with time if the contraction is sustained beyond 10 s (Macefield, Hagbarth, Gorman, Gandevia, & Burke, 1991) and this aspect would influence the results in a not easily predictable way. H reflex from the flexor carpi radialis (FCR) was measured. Vibration was applied through a vibrating handle (local vibration). As local vibration decreases rate and amplitude of Pacini's organs responses (Ilyinsky, 1965) which are fundamental for tactile perception (for review (Bell, Bolanowski, & Holmes, 1994)), these issues were addressed by testing the effects on fine fingertip dexterity through a standard Purdue test.

We expected a decrease in postural and kinetic tremor and H reflex due to an inhibited activity of the Ia afferents, and a decrease in the Purdue test score due to a decreased sensitivity in the hand and fingers.

2. Materials and methods

2.1. Participants

Ten male individuals (age 26.2 ± 3 years, body mass 68.9 ± 6.1 kg, stature 1.76 ± 0.1 m) with no history of neurological disorders participated in the experiment. Volunteers were required to abstain from caffeine, nicotine and alcohol on the testing day. The study was approved by the local research ethics board in accord with the Helsinki Declaration of 1975 and written informed consent was obtained from all volunteers before the onset of the experimental procedures.

2.2. Experimental design

The participants were requested to attend the laboratory for one single experimental session. Before starting data collection, the volunteers were prepared for EMG recording and completed five familiarisation trials for the Purdue task and five for the kinetic tremor task (details in the following sections). The experiment consisted in the measurement of: H reflex, postural and kinetic tremor and standard 30 s one hand Purdue test. Each assessment was performed two times in random order and was repeated at: baseline, after a control period and after local vibration. Local vibration was delivered by holding a vibrating handle for 120 s (more details in the "Vibration" section). The control period consisted in holding the same vibration device powered off for 120 s. Vibration was repeated twice: a first time immediately before H reflex measurements and a second time immediately before tremor and manual dexterity assessments. The vibration sequence was always performed after the control sequence to avoid any possible long lasting

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