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Tendon reflex is suppressed during whole-body vibration

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ABSTRACT

In this study we have investigated the effect of whole body vibration (WBV) on the tendon reflex (T-reflex) amplitude. Fifteen young adult healthy volunteer males were included in this study. Records of surface EMG of the right soleus muscle and accelerometer taped onto the right Achilles tendon were obtained while participant stood upright with the knees in extension, on the vibration platform. Tendon reflex was elicited before and during WBV. Subjects completed a set of WBV. Each WBV set consisted of six vibration sessions using different frequencies (25, 30, 35, 40, 45, 50 Hz) applied randomly. In each WBV session the Achilles tendon was tapped five times with a custom-made reflex hammer. The mean peak-to-peak (PP) amplitude of T-reflex was 1139.11 ± 498.99 μV before vibration. It decreased significantly during WBV ($p < 0.0001$). The maximum PP amplitude of T-reflex was 1333 ± 515 μV before vibration. It decreased significantly during WBV ($p < 0.0001$). No significant differences were obtained in the mean acceleration values of Achilles tendon with tapping between before and during vibration sessions. This study showed that T-reflex is suppressed during WBV. T-reflex suppression indicates that the spindle primary afferents must have been pre-synaptically inhibited during WBV similar to the findings in high frequency tendon vibration studies.

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1. Introduction

The use of whole-body vibration (WBV) is becoming an increasingly popular topic in scientific research due to its beneficial effects on neuromuscular performance. WBV elicits muscular contractions, resulting in general improvement in muscular function, enhanced physical strength, better balance, reduced fear of falling, and has positive effects on postural control (Cidem et al., 2014; Cochrane, 2011a, 2011b; Shim et al., 2014).

Increased myoelectric activity observed during the isolated vibration applied to muscle belly or tendon is explained with the Tonic Vibration Reflex (TVR) (de Ruiter et al., 2003; Matthews, 1966; Rittweger, 2010). TVR activates the muscle spindles, thereby enhancing the excitatory drive to the alpha motor neurons via Group Ia afferents (Matthews, 1966; Rittweger, 2010). Although, the direct evidence is lacking, many articles claim that the effect of WBV on neuromuscular performance can be explained through TVR (Cochrane, 2011a, 2011b; Rittweger, 2010; Pollock et al., 2012; Ritzmann et al., 2010).

H-reflex, analogous to TVR, is obtained by electrically stimulating Ia afferents bypassing the muscle spindle. It has been reported that H-reflex is suppressed during isolated muscle/tendon vibration and during WBV (Cakar et al., 2014; Gillies et al., 1969; Ritzmann et al., 2013a, 2013b). This suppression has been explained by presynaptic inhibition of Ia afferents. The myoelectric activity has also been reported to increase during vibration (Ashby et al., 1987; Cidem et al., 2014; Gillies et al., 1969; Hazell et al., 2007). It seems paradoxical that an increase in the myoelectric activity coexists with the H-reflex suppression during vibration. This phenomenon has been defined as the vibration paradox (Desmedt and Godaux, 1978). If the H-reflex is suppressed during vibration, how can we explain the increase in reflex myoelectric activity during vibration?

It is proposed that the fundamental differences between the H-reflex and the TVR may explain this paradox. That is, while vibration suppresses the H-reflex it may not suppress the TVR due to one basic reason: While H-reflex is elicited using electrical stimulation, TVR is induced through mechanical stimulation. Electric current is an artificial stimulus and may stimulate various

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nerve fibers including muscle spindle afferents simultaneously. It is not possible to be sure whether other nerve fibers are simultaneously stimulated causing the H-reflex suppression.

Like the H-reflex, T-reflex is analogous to TVR. However, T-reflex has an advantage over H-reflex since a mechanical stimulation instead of an electrical stimulation is used to obtain the reflex muscle response. Similar to the TVR, the mechanical stimulation to elicit T-reflex also activates muscle spindles directly (Ritzmann et al., 2013a, 2013b). Therefore, T-reflex may be more suitable for determining the role of the spindle pathways during WBV. If the muscle spindle and TVR play a role in vibration-induced reflex response, the amplitude of T-reflex should increase during WBV unless the T-reflex is already at a maximum level in the pre-WBV condition. It is therefore hypothesized that the amplitude of T-reflex should increase during WBV. Aim of this study is to test this hypothesis. Our previous research showed that amplitude of the vibration induced muscular reflex increases with WBV frequency (Cakar et al., 2015). Therefore our hypothesis was tested by using various WBV frequencies in the present study.

2. Methods

2.1. Participants

Fifteen young, healthy and right hand dominant male adult volunteers were included in this study. The mean age of the participants was 30 (24–43) years. The mean height and BMI were 175 ± 6 cm and 25.0 ± 3.4 kg/m^2, respectively. All volunteers provided their written informed consent prior to participation in any experimental procedures. All procedures were performed in accordance with the Declaration of Helsinki and were approved by the local ethics committee (local ethics committee: 2013/102).

2.2. Procedure

Prior to the induction of WBV, control T-reflex recordings were elicited and then the participants completed a 15-s trial WBV protocol to familiarize themselves with the procedure. Following the control T-reflex recordings, the trial protocol and a 15-s rest, the participants received a set of WBV and T-reflex stimuli during WBV. A WBV set consisted of six vibration periods, each lasting for 16 s, with 3-s rest intervals between periods. Within each set, WBV frequencies of 25, 30, 35, 40, 45, and 50 Hz were delivered in random order to negate any order effect.

The surface electromyography (SEMG) and accelerometer data were obtained while the participants stood upright on the vibration platform with the knees in extension (Fig. 1). The participants were barefooted and stood directly on the vibration platform. The vibrations (2.2-mm vertical displacements) were performed using a PowerPlate® Pro5 WBV (PowerPlate® International, Ltd. London, UK).

2.3. Data recordings

The recordings of T-reflex were acquired using surface electromyography (SEMG). The Ag/AgCl electrodes (KENDALL® Arbo) with a disc radius of 10 mm were placed 20 mm apart on the right soleus muscle belly on shaved skin that had been cleaned with alcohol in accordance with the recommendations of the Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles (SENIAM) project (Hermens et al., 2000). The ground electrode was placed on the lateral malleolus. The sampling frequency was selected as 10 kHz.

A custom-made reflex hammer tapped the right Achilles tendon just caudal to the accelerometer with a force of about 19.6 N

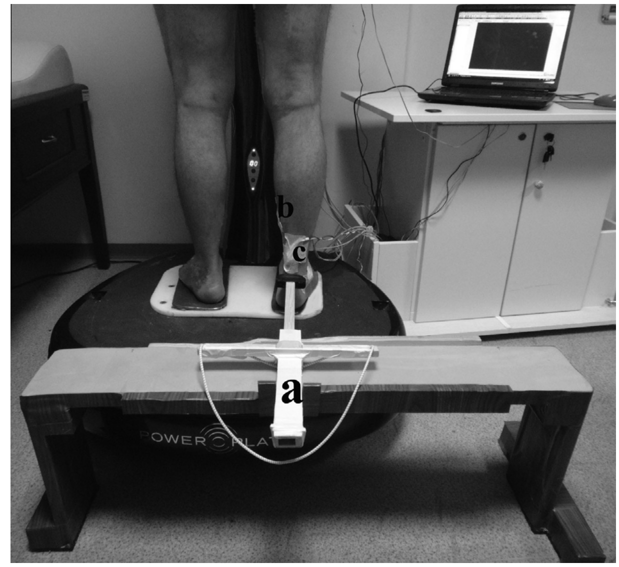

Fig. 1. Experimental setup. (a) Custom-made reflex hammer, (b) surface electrodes placed on the right soleus muscle, (c) accelerometer taped on the right Achilles tendon. The reflex hammer tapped the right Achilles tendon just caudal to the accelerometer. The recordings of T-reflex were elicited using surface electromyography before and during WBV.

(Fig. 1). In each vibration session, the Achilles tendon was tapped five times with approximately 3-s intervals between taps.

A light (2.9 g) tri-axial MEMS piezo-accelerometer (LIS344ALH, full-scale of ±6 g, linear accelerometer, ECOPACK®) was taped on the right Achilles tendon to determine the timing of the onset of the mechanical stimulus for the T-reflex and to measure stroke intensity of reflex hammer to Achilles tendon (Fig. 1). Acceleration unit used in this study was m/s^2.

2.4. Data processing

SEMG and accelerometer data were recorded using a PowerLAB® data acquisition system (ADInstruments, Oxford, United Kingdom) and the data were analyzed offline using the LabChart7® (ver 7.3.7, ADInstruments, Oxford, United Kingdom) software. All accelerometer recordings were filtered with high-pass filter set at 5 Hz. All EMG recordings were filtered using a band pass filter from 80 to 500 Hz to avoid WBV induced movement artifacts (Sebik et al., 2013).

The maximum peak-to-peak (P-P) amplitude of T-reflex (Tmax), and the mean P-P amplitude of T-reflex (Tmean) were determined for each vibration session. The mean P-P amplitude of acceleration (ACCmean) was calculated for each vibration session. Amplitude of acceleration corresponding to the Tmax (ACCtmax) was also determined. It was found that the relative intraobserver error (rIE) was 6.76% for Tmean, 9.44% for Tmax, 2.29% for ACCmean and 2.16% for ACCtmax in this study.

2.5. Statistical analysis

The normal distribution of the data was confirmed using the Kolmogorov-Smirnov test. Continuous variables were summarized as arithmetic mean and standard deviation (SD). General linear model repeated measures test was used to compare the T-reflexes before and during vibration. The Bonferroni test was applied for pair-wise comparisons (PostHoc analyses). Confidence interval (CI), mean, and standard error (SE) were calculated for all data. When comparing means of two data sets, if ±95% CI of one data set included the mean of another data set, it was

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