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Effect of Whole Body Vibration Stimulus and Voluntary Contraction on Motoneuron Pool

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Abstract

NISHIHIRA, Y., IWASAKI, T., HATTA, A., WASAK, T., KANADA, T., KUROIWA, K., AKIYAMA, S., KIDA, T. and RYOL, K.S ., Effect of Whole Body Vibration Stimulus and Voluntary Contraction on Motoneuron Pool., Adv. Exerc. Sports Physiol., Vol.8, No.4 pp.83-86, 2002. We investigated the influence of transient whole body vibration and voluntary contraction on the motorneuron pool. Electromyographic recordings were obtained from the soleus muscle of 17 healthy subjects using surface electrodes placed bilaterally. Whole body vibration was applied in three sets of 3 minutes each using a training device, Galileo 2000 (Novotec Gmbh, Gemany). The H-reflex was elicited by electrically stimulating the right posterior tibial nerve, as subjects sat in a chair in a relaxed position. The H/M ratio was significantly increased after vibration compared to before vibration. This suggests an increase in the excitability of the alpha motoneuron pool. In this study, it may be considered that the H/M ratio increased as a result of the integration of influences from both whole body vibration and voluntary contraction.

Keywords: whole body vibration, voluntary contraction, motoneuron pool.

Introduction

It is a problem that the elderly can not perform hard muscular training using weight training machines, because of decreased muscular strength due to aging. However, with the aim of improving physical fitness, Shiessel recently developed a rehabilitation device that gives the human body vibration stimulus through the soles of both the left and right feet. This device moves up and down in a vertical line like a seesaw, centered the middle of the diaphragm. The subjects are requested to consciously maintain isometric contraction of the legs in order to oppose the whole body vibration stimulus. rom the motor area affect the excitation of the spinal motoneuron pool as an effect of voluntary contraction on the central nervous system. Moreover, it is reported that the respiration and circulation system, the muscles in the legs, maximal isometric muscular strength, jumping height, balance and walking ability are improved, as an effect of whole body vibration stimulus and voluntary contraction on human body (8, 12, 10, 13). However, the effects of whole body vibration stimulus and voluntary contraction on the central nervous system remain unclear.

In this study, we investigated whether the motoneuron pool is actually affected by whole body vibration stimulus and voluntary contraction.

Methods

Subjects. 17 neurologically normal volunteers aged between 19 and 28 years old, all of whom gave informed, consent participated in this study.

Experimental procedure. The machine, known as Galileo 2000 (Novotec, GmbH, Germany), is used in order to the give whole body vibration stimulus. The whole vibration stimulus from the sole of the left and right feet was 3 minutes one time (shake frequency 25Hz)×3 sets with a set interval was 10 minutes. During whole body vibration stimulus, the knees and were maintained at approximately 120° and 100° angles. The subjects were requested to consciously maintain isometric contraction of the legs in order to oppose the whole vibration stimulus, and during that time, they were asked to place their hands on their waist. To measure H-reflexes, the subjects rested comfortably in an armchair and were instructed to maintain a relatively stable arousal level of consciousness. The sensory threshold, H threshold, M threshold, Hmax, and Mmax were measured within five minutes before and after whole body vibration stimulus of three minutes during the experiment. For the measured items, the first value before whole body vibration stimulus was defined as the control, the first value after whole body vibration stimulus was defined as post 1, the second was post 2, and the third was post 3.

To measure H-reflexes and M-responses, paired surface electrodes were attached to the skin of the belly over the soleus muscle with less than 5 kΩ electrical resistance. For electrical stimulation, an anodal electrode was placed

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on the skin of the patella and a cathode was placed at a suitable spot to stimulate the tibial nerve at the popliteal fossa, with careful avoidance of undesirable current spreading to other nerve branches. Rectangular electrical pulses, 1ms in duration, were applied at a rate of once every 3 s. The intensity of these pulses was gradually increased from one lower than the threshold of the H-reflex to higher than the saturated state of the maximal M-response. Gradual increases in stimulus intensity were employed in an attempt to avoid any psychological stress by unexpectedly administering a high intensity pulse unexpectedly to the subject.

The muscle responses evoked were amplified via a band-pass filter with a range of 20Hz-1.5kHz. A stimulator (Nihonkouden) coupled with an isolator (Nihonkouden), of which the output ranged from 0 to 200 V, was used for electrical stimulation. Analog outputs from electroencephalography apparatus were transformed into digital data at a sampling rate of 5kHz by an A-D converter installed in a personal computer (NEC) and stored on a hard disk drive as source data for subsequent analyses. EMG was analyzed in the range from 30msec before stimulus to 120msec after stimulus. After completion of the experiment, the H-reflexes and M-responses were analyzed on software installed in a personal computer. The amplitudes of the H-reflexes and M-responses were evaluated by the peak to peak method.

The difference in Hmax, Mmax, H threshold, M threshold, sensory threshold, and H/M between before and after stimulus were analyzed using the paired t-test after confirming the equal variance of each group by the F-test. To decrease the experimental error rate due to repeated t-tests on multiple dependent variables, we adjusted the a prior statistical probability using the Bonferroni method resulting in a corrected alpha of 0.0167.

Results

Fig.1 shows the changes of Hmax during the 3 minutes after whole body vibration stimulus. Comparing the Hmax during this time, only the Hmax of post 2 (Hmax after the second whole body vibration stimulus) was significantly increased ($P<0.05$) and no significant difference was found for Mmax.

Fig.2 shows the changes in H/M before and after whole body vibration stimulus. Comparing H/M in post 1(H/M after the first whole body vibration stimulus), post 2 (H/M after the second whole body vibration stimulus), post 3 (H/M after the third whole body vibration stimulus) with that in pre (H/M before whole body vibration stimulus), H/M post 1, in post 2 and post 3 were significantly increased (post 1, $P<0.05$; post 2, $P<0.01$; post 3, $P<0.05$).

Figs. 3 and 4 show the changes in Hth and Mth before and after whole body vibration stimulus. Comparing Hth and Mth before and after whole body vibration stimulus, Hth and Mth after whole body vibration stimulus were significantly decreased ($P<0.05$).

Fig. 5 shows the changes in the sensory threshold before whole body vibration stimulus. Comparing the sensory threshold before and after whole body vibration stimulus, the sensory threshold after the treatment was significantly decreased (post 1, $P<0.01$; post 2, $P<0.01$; post 3, $P<0.05$).

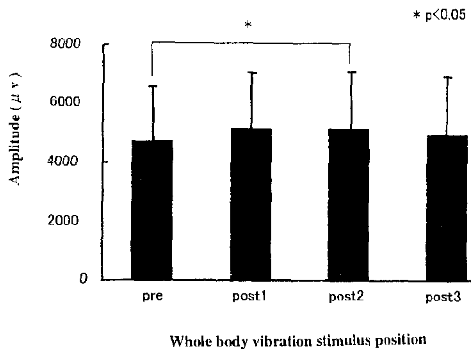

Fig. 1 The changes of Hmax and Mmax during 3 minutes after whole body vibration stimulus. Comparing the Hmax with the changes during 3 minutes after whole body vibration stimulus, only the Hmax of post 2 significantly increased and no significant difference was found for Mmax.
Pre: position before whole body vibration stimulus, post 1: the first position after whole body vibration stimulus, post 2: the second position after whole body vibration stimulus, post 3: third position after whole body vibration stimulus

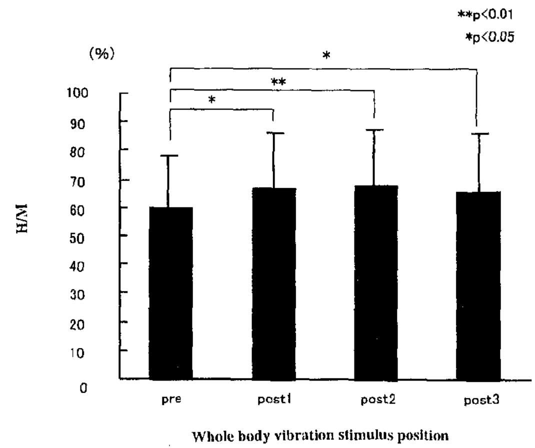

Fig. 2 The changes of H/M before and after whole body vibration stimulus. Comparing H/M in post 1, post 2, and post 3 with that in pre, H/M in post 1, post 2 and post 3 were significantly increased.
Pre: position before whole body vibration stimulus, post 1: the first position after whole body vibration stimulus, post 2: the second position after whole body vibration stimulus, post 3: third position after whole body vibration stimulus

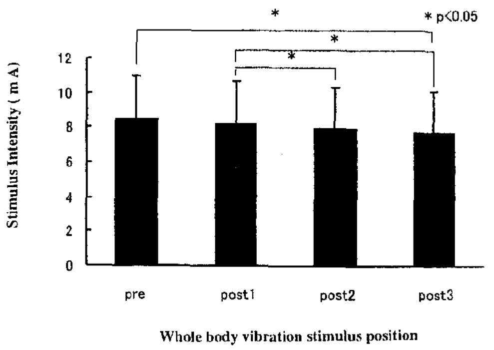

Fig. 3 The changes in Hth before and after whole body vibration stimulus. Comparing Hth before and after whole body vibration stimulus, Hth after the treatment was significantly decreased.

Pre: position before whole body vibration stimulus, post 1: the first position after whole body vibration stimulus, post 2: the second position after whole body vibration stimulus, post 3: third position after whole body vibration stimulus

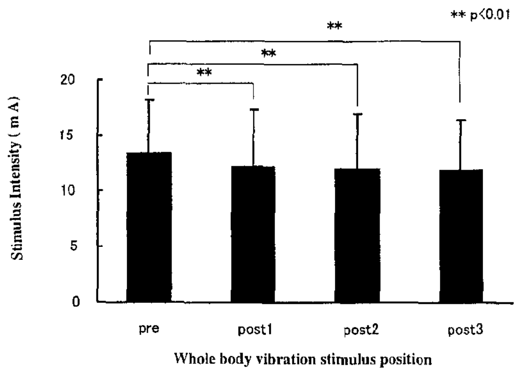

Fig. 4 The changes in Mth before and after whole body vibration stimulus. Comparing Mth before and after whole body vibration stimulus, Mth after the treatment was significantly decreased.

Pre: position before whole body vibration stimulus, post 1: the first position after whole body vibration stimulus, post 2: the second position after whole body vibration stimulus, post 3: third position after whole body vibration stimulus

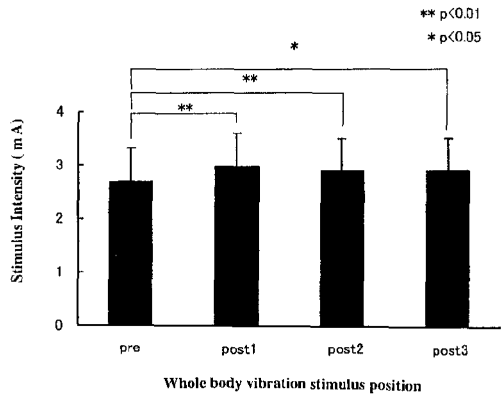

Fig. 5 The changes in the sensory threshold before whole body vibration stimulus. Comparing the sensory threshold before and after whole body vibration stimulus, sensory threshold after the treatment was significantly decreased.

Pre: position before whole body vibration stimulus, post 1: the first position after whole body vibration stimulus, post 2: the second position after whole body vibration stimulus, post 3: third position after whole body vibration

Discussion

We investigated whether the motoneuron pool is actually affected by whole body vibration stimulus and voluntary contraction. The main finding of this study was that H/M was significantly increased in post 1, post 2, post 3, comparing with pre. However, as compared with H/M in post 1, no significant difference was found in post 2 or post 3. Therefore, it is considered that motoneuron excitation motoneuron peaked after whole body vibration stimulus of 3 minutes×3 sets. In this experiment, H/M was evaluated by measuring the Hmax and Mmax within 5 minutes after whole body vibration stimulus. As a cause of these variations, it is necessary to consider the after-effects on the whole body after transitory whole body vibration stimulus, the mechanisms of which are as followings; 1) post-vibration inhibition, 2) post-vibration potentiation, 3) post-voluntary contraction inhibition.

Roll et al. reported that when whole body vibration stimulus (vibration frequency of 18Hz, 15 minutes in duration) is given in the sitting position, the H-reflex amplitudes were decreased over several minutes during and after the treatment (7). As the vibration frequency used in this study was close to that of the preceding study, it was expected that H-reflex amplitudes would decrease. However, the result was contrary to the expectations. As the cause of these results, influences other than vibration stimulus and different local vibrations were considered. It was confirmed that the post-vibration potentiation, by which the H-reflex amplitude is increased, is evoked by optimal stimulus frequency (i.e. 100 Hz~250Hz). A vibration frequency of about 180Hz lasting 5 minutes was effective, but this effect lasted only several minutes. The H-reflex amplitude increased temporarily after vibration stimulus, when high frequency vibration stimulus was given to the triceps of the leg. It is known from recording the H-reflex from over the soleus by electrical stimulus to the Achilles once every 3sec, that H-reflex amplitude decreased when the stimulus started and gradually recovered when the stimulus stopped. However, as the stimulus used in this experiment was whole body vibration, it differed from that of the preceding study. Furthermore, in this study, it is considered that voluntary contraction influenced the H-reflex amplitude, because of consciously maintaining isometric contraction of the legs. In addition, it was confirmed that H-reflex was vigorously inhibited after voluntary contraction (1, 5). However, it is known that this inhibition lasts only 10~15sec after voluntary contraction (4), therefore, in this study, it seems possible that the inhibition lasted 4~5minutes after voluntary contraction is ceased. As voluntary contraction was performed together with whole body vibration stimulus, this experiment was different from that of the preceding study.

In this study, it is supposed that afferents from Ia fiber were increased by whole body vibration stimulus and that the descending commands to the motoneuron pool following voluntary contraction were also increased. As a result, it may be concluded that excitation of the motoneuron pool was increased by the influence of both whole body vibration stimulus and voluntary contraction.

References

1) Crone C and Nielsen J (1989) Methodological implications of the post activation depression of the soleus H-reflex in man. Exp. Brain Res 78: 28-32
2) Gottlieb GC and Agarwal GC (1971) Dynamic relationship between isometric muscle tension and the electromyogram in man. J Appl 3: 345-351
3) Kasai T (1994) An analysis of human voluntary movement by reaction time and H reflex tecnique. J J Sports Sci 13: 131-142
4) Maehara T, Kato T, Kikuchi K and Kasai T (1995) Pastexercise effects on H reflex and motor evoked potentials (MEPs) of FCR muscle. J J Sports Sci 14: 647-656
5) Moore MA and Kukulka CG (1991) Depression of Hoffmann reflexs following voluntary contraction and implications for proprioceptive neuromuscular facilitation therapy. Phys Ther 71: 321-329
6) Rittwerger J, Wilhelm G, Armbrecht G, Bolze X, Gowin W and Felsenberg D (1998) Acute Physiological effects of training with galileo 2000. First results. Osteoporosis international 8-3: 121
7) Roll JP, Martin B, Gauthier GM, Mussa Ivaldi F (1980) Effects of whole-body vibration on spinal reflexes in man. Aviat Space Environ Med 51: 1227-1233
8) Runge M, Rehfeld G and Resnicek E (2000) Balance training and exercise in geriatric patients. J Musculoskeletal Interactions. 1: 54-58
9) Tanaka R (1986) The Hoffmann reflex. Journal of The Physiological Society of Japan. 48: 719-734
10) Wilhelm G, Rittwerger J, Armbrecht G, Bolze X, Gowin W and Felsenberg D (1998) Evaluation of the long term effects Galileo 2000 in a randomized controlled study. Osteoporosis international 8: 121

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