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Effects of Lower Limb Vibrations in the Supine Position on Autonomic Activity in Healthy Adults

Akiko Noda[1,2,3], Sayuri Tsukano[4], Seiko Miyata[5], Shinsuke Inoue[6], Kumiko Honda[2] and Fumihiko Yasuma[7]

[1]Department of Biomedical Sciences, Chubu University Graduate School of Life and Health Sciences, 1200 Matsumoto-cho, Kasugai-shi, Aichi, 487-8501, Japan

[2]Chubu University College of Life and Health Sciences, 1200 Matsumoto-cho, Kasugai-shi, Aichi, 487-8501, Japan

[3]Innovative Research Center for Preventive Medical Engineering, Nagoya University, Furo-cho, Chikusa-ku, Nagoya-shi,Aichi, 464-8601, Japan

[4]Department of Medical Technology, Nagoya University School of Health Sciences, 1-1-20 Daiko-Minami, Higashi-ku, Nagoya-shi, Aichi, 461-8673, Japan

[5]Department of Psychiatry, Nagoya University Graduate School of Medicine, 65 Tsurumai-cho, Showa-ku, Nagoya-shi, Aichi, 466-8550, Japan

[6]Aisin Seiki Co., Ltd, 2-1 Asahi-cho, Kariya-shi, Aichi, 448-8650, Japan

[7]Department of Cardiology, Suzuka National Hospital, 3-2-1 Kasado, Suzuka-shi, Mie, 513-8501, Japan

*Corresponding author: Akiko Noda, Department of Biomedical Sciences, Chubu University Graduate School of Life and Health Sciences, 1200 Matsumoto-cho, Kasugai-shi, Aichi, 487-8501, Japan, Tel: +81-568-51-9906; Fax: +81-568-51-5370; E-mail: anoda@isc.chubu.ac.jp

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Abstract

Background: Short duration massage of the lower limbs reduces fatigue sensation in working adults. However, the effects of lower limb vibrations on autonomic activity, which potentially could improve sleep onset, have not been fully investigated. This study aimed to examine the effects of lower limb vibrations on heart rate variability (HRV) as a marker of autonomic activity.

Methods: The study involved two aspects. In the first experiment, the optimal frequency of vibration was determined in five healthy adults (one male and four females; mean age, 20.4 ± 0.5 years). The second experiment involved assessing the effects of vibration at the optimal frequency on nine healthy adults (four males and five females; mean age, 26.3 ± 16.8 years). Electrocardiograms (recorded with bipolar lead CM5) were obtained in the supine position, and HRV was used as an index for autonomic activity. The power spectra at 0.04-0.15 Hz (low frequency (LF) power) and 0.15-0.40 Hz (high frequency (HF) power) were quantified, and HF power and LF/HF ratio were calculated. In the first experiment, vibrations at four different frequencies (i.e., 25, 30, 35, and 40 Hz) were randomly applied for 10 minutes. In the second experiment, HF power and LF/HF ratio were measured at a vibration frequency of 35 Hz for 10 minutes and for 10 minutes of interruption. As a control, HF power and LF/HF ratio were recorded for 20 minutes without vibration.

Findings: The percent change in HF power tended to be higher at a vibration frequency of 35 Hz compared to vibrations at frequencies of 25, 30, and 40 Hz. Vibrations at this frequency significantly increased HF power and reduced the LF/HF ratio compared to when vibrations were not applied.

Conclusion: Our findings suggest that the lower limbs vibration in the supine position at the frequency of 35 Hz may increase parasympathetic activity and presumably promote the rapid onset of sleep.

Keywords: Lower limb vibrations; Massage; Heart rate variability; Sympathetic activity; Parasympathetic activity; Sleep

Introduction

Vibration and massage therapy has been used developed in sports, geriatric medicine, and rehabilitation. Low frequency (below 40 Hz) vibrations applied to the whole body, or just a particular part of the body promote relaxation to ameliorate fatigue sensation. The whole body vibrations also improve muscular strength and performance, as well as skin blood flow [1-4]. Previous study demonstrated that 20 minutes of compression on trigger points in the leg muscle augmented parasympathetic activity and improved subjective fatigue sensation in healthy young adult women [5]. However, the effects of lower limb vibrations on autonomic activity, which potentially could improve sleep onset, have not been fully investigated.

Heart rate variability (HRV) with power spectra quantified at 0.04-0.15 Hz (low frequency (LF) power) and 0.15-0.40 Hz (high frequency (HF) power) reflects autonomic activity in the clinical practice, and HF power and LF/HF have been widely used as indices of parasympathetic and sympathetic activity, respectively [6]. Sympathetic activity, blood pressure, and heart rate are lower in normal individuals while they are in non-REM sleep than those while they are awake [7]. When comparing patients with insomnia and good sleeper, autonomic dysfunction as assessed by HRV was observed in patients with insomnia, particularly in relation to vagal activity [8].

In the present study, we examined the effects of lower limb vibrations in the supine position on autonomic activity.

Methods

Subjects

The first experiment was undertaken in five healthy adults (one male and four females; mean age, 20.4 ± 0.5 years), and the second experiment in nine healthy adults (four males and five females; mean age, 26.3 ± 16.8 years). The protocol of this study was approved by the Ethics Review Committee of Nagoya University School of Medicine, and the subjects were informed of the objectives and conditions of the experiments prior to participation.

Experimental design

Vibrations were applied to the lower limbs with subjects in the supine position while awake using a prototype mattress with a vibration unit developed by Aisin Seiki Co., Ltd.. Forced vibrations were applied, in which the frequency of the external force was almost identical to the resonance frequency, allowing for efficient vibrations mechanically. The mattress was approved as being safe for use on the human body, as required by ISO 2361-1(1997).

Selection of vibration frequency

To identify the optimal frequency, vibrations at different frequencies (i.e., 25, 30, 35, and 40 Hz) were applied to the lower limbs of subjects for 10 minutes. Electrocardiograms (recorded with bipolar CM5) were obtained, and HRV (Memcalc/Win, GMS Co., Tokyo) was calculated using the R-R interval. The power spectra at 0.04-0.15 Hz (LF power) and 0.15-0.40 Hz (HF power) were quantified. HF power and LF/HF ratio were evaluated, and percent changes from baseline were calculated and compared between frequencies.

HF power and LF/HF measurements at 35 Hz

Standard polysomnography was performed, and electroencephalograms (O1-A2, O2-A1) were used to confirm wakefulness. HF power and LF/HF ratio were measured at a vibration frequency of 35 Hz for 10 minutes and for 10 minute of interruption. As a control, these parameters were recorded for 20 minutes without vibration.

Data analysis

Data are presented as mean ± standard error and analyzed by analysis of variance (ANOVA), followed by Scheffe's test. Two-way repeated-measures ANOVA and Bonferroni-type multiple comparison were performed to HF power and LF/HF ratio across different vibration frequencies. All analyses were performed using Statview (SAS Institute Inc; Cary, NC). A value of $p<0.05$ was considered statistically significant.

Result

Selection of vibration frequency

Changes in HF power tended to be higher after applying the vibration at a frequency of 35 Hz compared to vibrations at frequencies of 25, 30, and 40 Hz. The LF/HF ratio did not significantly differ across the tested frequencies (**Figure 1**).

HF power and LF/HF at 35 Hz

This prototype had a 35 Hz resonant frequency (**Figure 2**). HF power significantly increased (p=0.048), while LF/HF ratio decreased, when a vibration at 35 Hz was applied, compared to when no vibrations were applied (**Figure 3**).

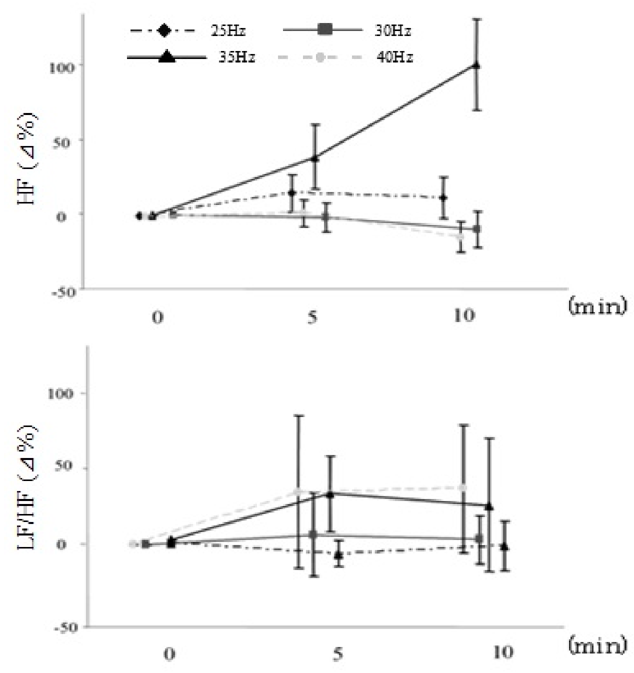

Figure 1: Time course of percent changes in HF power (upper panel) and LF/HF (lower panel) at each frequency. (HF, high frequency; LF, low frequency).

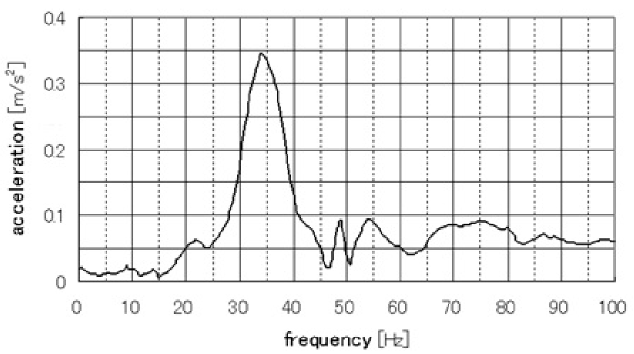

Figure 2: Resonance characteristics.

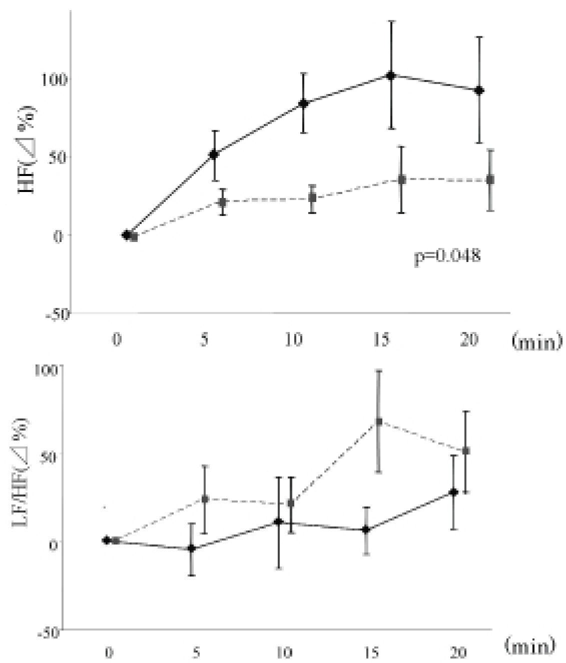

Figure 3: Time course of percent changes in HF power and LF/HF at a vibration frequency of 35 Hz. Solid line: vibrations for 10 minutes. Dotted line: no vibrations. (HF, high frequency; LF, low frequency).

Discussion

In this study, we found that HF power, which reflects parasympathetic activity, tended to increase at a vibration frequency of 35 Hz compared with frequencies of 25, 30, and 40 Hz. HF power also significantly increased with vibrations at a frequency of 35 Hz compared to without a vibration. These findings suggest that the lower limb vibrations at 35 Hz in the supine position may augment the HF power, thereby reflecting an increase in parasympathetic activity and presumably ameliorating difficulties with sleep initiation.

Previous studies have shown that lower limb massage increases parasympathetic activity and improves subjective fatigue sensation [5], and that subjective fatigue sensation is significantly associated with muscle sympathetic nerve activity [9]. The augmented parasympathetic activity presumably decreases muscle sympathetic activity, which may be involved in the relieving of fatigue sensation. Augmented parasympathetic activity has also been reported to increase peripheral blood flow [10], contributing to the alleviation of chronic muscle pain [10-12]. In this context, the lower limb vibrations at a frequency of 35 Hz may contribute to muscle relaxation and fatigue recovery.

Fatigue can be efficiently alleviated with natural rest and sleep, and it is also important to reduce fatigue by means of machines that enhance self-recovery. Appropriate use of physiotherapy equipment, such as the vibration machine described herein, is effective not only for alleviating fatigue, but also for preventing the unnecessary prescription of medication. While we found that short duration (i.e., 10 minutes) lower limb vibrations increased parasympathetic activity, additional studies will be needed to determine more the optimal methodology of vibration, frequency, duration, and intensity of the machinery assistance, and also to determine the long-term effects of vibration on autonomic activity and other physiologic functions. External or artificial technologies to promote recovery from difficulties with initiating sleep are expected to be useful for ordinary people including athletes as well as geriatric and working populations, who are exposed to physical and mental stress.

In conclusion, our findings suggest that lower limb vibrations in the supine position at a frequency of 35 Hz may increase parasympathetic activity and lead to comfortable sleep onset.

Conflict of Interest

None of the authors has any conflict of interest to disclose.

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