Music Can Enhance Exercise-Induced Sympathetic Dominancy Assessed by Heart Rate Variability

KAYOKO URAKAWA and KAZUHITO YOKOYAMA

School of Nursing, Faculty of Medicine, Mie University, and

1Department of Public Health and Occupational Medicine, Graduate School of Medicine, Mie University, Tsu, Japan

URAKAWA, K. and YOKOYAMA, K. Music Can Enhance Exercise-Induced Sympathetic Dominancy Assessed by Heart Rate Variability. Tohoku J. Exp. Med., 2005, 206 (3), 213-218 —— Many studies have been conducted on physiological responses of music, yielding controversial results. In the present study, we examined whether music affects the exercise-induced changes in the autonomic nervous system activity in twelve healthy female college students. On the first day, the subjects were asked to rest, exercise, and then rest for 15 min, respectively. On the second day, they were asked to rest with music, exercise, and then rest with music for 15 min, respectively. Heart rate variability was measured for the pre- and post-exercise periods. Music was given according to subjects’ preferences using a vibroacoustic apparatus (body sonic system), i.e. a chair on which subjects laid and felt low-pitch sounds by their body in addition to listening music. With music, ratio of low frequency to high frequency component of heart rate variability (LH/HF) was significantly increased after exercise as compared with before exercise ($p < 0.01$). By contrast, the changes in LH/HF were not significant without music ($p > 0.05$). It is suggested that after exercise in which sympathetic nerve activity is dominant, preferred music synchronizes with the activated physical response, further promoting the response and increasing sympathetic nerve activity. Combining music with exercise is therefore not only enjoyable in terms of mood but also may promote physiological excitation and enhance physical activation. ——— music; body sonic system; exercise; heart rate variability; autonomic nervous system

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In music therapy, the therapeutic use of emotions elicited by listening to music is a form of appreciation therapy in receptive music therapy. Music appreciation in everyday life is used for pleasure and for its mood-changing effects rather than for any intentional therapeutic benefits. Also, a vibroacoustic method (body sonic system), by which subjects listened to music as well as feel it as vibration through electronic-mechanic transducers, has been developed to enhance the effects of music in therapeutic use (Wigram and Dileo 1997).

Research on the biological effects of music stimulation began with work on its psychological effects, which has been followed by experimental work on physiological changes including the body sonic system, such as blood pressure, heart rate, and salivary IgA as indicators suggested that mu-
sic has physiological effects, but no consistent tendencies in the physiological response have been identified (McCraty et al. 1996; Byers and Smyth 1997; Iga et al. 1997; Charnetski et al. 1998; Yoshimitus et al. 2000; Knight and Rickard 2001). This could be attributable to various factors, including the music stimulation used as an experimental condition, the presentation time, the physical environment, whether or not a control group is used, the particular physiological and psychological characteristics of the subjects, and the issue of preference etc.

In recent years, heart rate variability has been used as an indicator of autonomic nerve activity, in addition to variables such as electroencephalogram, blood pressure, respiration, and heart rate. In frequency analysis of heart rate variation, frequency is divided into a low-frequency component (LF; 0.04–0.15 Hz) and a high-frequency component (HF; 0.15–0.40 Hz). The ratio of the low- and high-frequency components (LF/HF) can then be determined to obtain a relative indicator of parasympathicotonia and sympathicotonia (Pagani et al. 1986; Hayano et al. 1990a,b; Ewing 1992; Murata et al. 1992; Unalacak et al. 2004). Both the sympathetic and parasympathetic nervous systems are involved in the LF component, whereas the HF component shows stimulation of the parasympathetic nervous system. An increase in LF/HF is therefore believed to be an indicator of increased sympathetic nervous system activity (Hayano et al. 1991).

In a spectral analysis of heart rate variation waveforms as a result of music stimulation, examination of the respiratory variation component in the vicinity of 0.25 Hz (respiratory sinus arrhythmia [RSA]) and the arterial blood pressure variation component in the vicinity of 0.1 Hz (Mayer wave sinus arrhythmia) showed that the RSA component tended to increase more when subjects were concentrating on music than when they were resting, suggesting that music affects the parasympathetic nervous system (Hoshishiba 1995). Accumulating data on the physiological effects of music using heart rate variability as an indicator under various experimental conditions and determining the scientific basis for these effects are essential as basic research to further promote the therapeutic use of music.

The objective of the present study is to investigate whether music affects the exercise-induced changes in the autonomic nervous system activity. As exercise may lead to sympathetic dominance (Perini and Veiscsteinas 2003), our concern is to elucidate the effect of music is synergistic or antagonistic. The present study utilizes the body sonic system, expecting the effects greater than just listening to music.

**SUBJECTS AND METHODS**

**Subjects**

Subjects examined were 12 healthy female college students with a mean age of 21.9 years (range, 20–37 years). Written consent for participation in the study was obtained after the subjects had been informed of the nature of the study orally and in writing.

**Study procedures**

The study was approved by the Research Ethics Committee of Faculty of Medicine, Mie University (March 20, 2002), and conducted in two parts on 2 days during the period from April to July 2003. In the first part of the study, the subjects were requested to rest without music, exercise, and then rest without music for 15 min, respectively. In the second part, subjects were asked to bring music CDs based on their preference; they brought pop songs with lyrics (three subjects), jazz song (one), track of nature sounds (one), pieces of healing music (four), and classical tracks (three). They were requested to rest with music, exercise, and then rest with music for 15 min, respectively. The two parts of the study were conducted at the same time on the first and second days to avoid diurnal variation in the measured values.

During exercise, subject was asked to pedal a bicycle ergometer (Cardio Exercise Cycle System 5RH, COMBI Company, Tokyo) for 15 min; heart rates were monitored and maintained in the range given by the Karvonen’s formula \[ (220 – \text{age}) – \text{resting heart rate} \times (0.4 \text{ to } 0.6) + \text{resting heart rate} \], with changing the load of pedals by a microcomputer in the ergometer. This level was chosen because it was equivalent to approximately 9–12 scores for the rating of perceived exertion (Borg index) assuming that resting heart rate is 70 / min for ages of 20s, which were safe and not uncomfortable to subjects (Sugi et al. 1988).
For the resting component either with or without music, the subject laid down on the body sonic chair (Relactive-1, Pioneer Company, Tokyo) set up in a dimly lit soundproof room maintained at a temperature of 22°C. The music was played from speakers built into system near subject’s head, and she adjusted the volume by herself. Subject also felt low-pitched sounds of music by their body through electronic-mechanic transducers built in the chair.

Electrocardiographic measurements and recordings were done with a High-Speed Power Lab Pack System (Bioresearch, Nagoya) before and after exercise, respectively (15 min for each). Calculation of LH and HF components was also performed by this system.

Statistical analysis

Differences in heart rate (HR), LF and HF components and LF/HF between pre- and post-exercise as well as between with and without music were assessed by paired t-test, respectively, using SPSS 11.0J for Windows statistics software (SPSS Inc., Chicago, IL, USA). Effects of music and exercise on these measurements were also assessed by the three-way analysis of variance with music (with or without), exercise (pre or post) and subjects (1 – 12) as factors.

RESULTS

Results are shown in Table 1. Before exercise, none of HR, LF, HF or LF/HF was significantly different between the conditions with and without music ($t = -0.828, 1.103, -0.798$ and $1.068$, respectively, $p > 0.05$). LF/HF ratios were significantly increased by exercise when subjects listened to music. By contrast, changes in LF/HF were not significant without music. Heart rates were significantly increased either with or without music. Fig. 1 illustrates alterations in LF/HF for 12 subjects. The analysis of variance showed the significant effect of exercise on LF/HF ($F = 7.349$, $p < 0.05$) and non-significant effect of music ($F = 0.299$, $p > 0.05$) and an interaction between exercise and music at a marginal significance level ($F = 3.092$, $p = 0.088$). Effects of exercise were also significant for HF ($F = 4.639$, $p < 0.05$) and HR ($F = 19.290$, $p < 0.001$) but not for LF ($F =

<p>| Table 1. Exercise-induced changes in heart rate (HR), low-frequency (LF) and high-frequency (HF) components of ECG heart rate interval variability with and without music in 12 female students: average with standard deviation in parenthesis |
|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th></th>
<th>With music</th>
<th>Without music</th>
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<tbody>
<tr>
<td>HR (beat/min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-exercise</td>
<td>69.32 (8.52)</td>
<td>67.59 (10.16)</td>
</tr>
<tr>
<td>Post-exercise</td>
<td>76.07 (5.47)</td>
<td>74.43 (7.09)</td>
</tr>
<tr>
<td>Difference $^a$</td>
<td>6.75 (7.37)$^*$</td>
<td>6.83 (7.12)$^*$</td>
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<tr>
<td>LF (msec$^2$)</td>
<td></td>
<td></td>
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<tr>
<td>Pre-exercise</td>
<td>355.53 (193.82)</td>
<td>514.10 (543.57)</td>
</tr>
<tr>
<td>Post-exercise</td>
<td>307.68 (248.70)</td>
<td>350.48 (273.84)</td>
</tr>
<tr>
<td>Difference $^a$</td>
<td>$-47.85$ (291.40)</td>
<td>$-163.62$ (342.28)</td>
</tr>
<tr>
<td>HF (msec$^2$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-exercise</td>
<td>1176.47 (1698.43)</td>
<td>765.33 (733.73)</td>
</tr>
<tr>
<td>Post-exercise</td>
<td>385.23 (393.77)</td>
<td>440.16 (507.27)</td>
</tr>
<tr>
<td>Difference $^a$</td>
<td>$-791.23$ (1454.09)</td>
<td>$-325.19$ (760.0)</td>
</tr>
<tr>
<td>LF/HF</td>
<td></td>
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<tr>
<td>Pre-exercise</td>
<td>0.998 (1.137)</td>
<td>1.213 (1.478)</td>
</tr>
<tr>
<td>Post-exercise</td>
<td>1.791 (1.712)</td>
<td>1.382 (1.067)</td>
</tr>
<tr>
<td>Difference $^a$</td>
<td>0.793 (0.701)$^*$</td>
<td>0.169 (0.914)</td>
</tr>
</tbody>
</table>

$^a$(Post-exercise) – (Pre-exercise).

$^*p < 0.01$ (between pre- and post-exercise, paired t-test)
Music did not show significant effects on these measurements ($p > 0.05$). The correlation coefficient (Spearman) for the LF/HF before and after exercise was 0.881 ($p < 0.001$) with music and 0.622 ($p < 0.05$) without music.

**DISCUSSION**

In a study by Kubo et al. (1996) in which 47 patients with ischemic heart disease were required to 1) lie resting for 15 min, 2) listen to music for 20 min, and then 3) lie resting for 15 min, in that order, the HF component increased when the patients were listening to selected music of their preference (classic, jazz, popular, and music box music) and continued to increase over the subsequent 15 min of rest, and LF/HF was lower after listening to music than before resting, suggesting that parasympathetic nervous system activity is enhanced by music. Using abdominal respiration, mental concentration, and Bach’s first movement of Brandenburg Concerto No. 1 as 1/f music, Yasumoto et al. (2001) had 7 female students 1) sit with their eyes open for 5 min, 2) breathe abdominally 6 times for 1 min while sitting with their eyes closed, 3) do a mental concentration exercise for 5 min while sitting with their eyes closed, 4) listen to 1/f music for 4 min and 30 sec, 5) do a mental concentration exercise for 5 min, and 6) meditate for 30 min, in that order. The HF% was scored using sitting as the standard. It was found that HF% variation every 10 min after listening to 1/f music increased, indicating that listening to music stimulated parasympathetic nervous system activity.

In the present study, heart rates were significantly increased by exercise (Table 1). The analysis of variance revealed significant effects on heart rates, HF, and LH/HF, with smaller HF and larger LF/HF after exercise (Table 1). These observations might have reflected increased sympathetic and/or decreased parasympathetic nerve activities, i.e., sympathetic dominance, by exercise, as previously reported (Perini and Veicsteinas 2003). Also, the sympathetic nerve activity as indicated by LF/HF ratio was significantly higher after exercise in the subjects when they listened to music. Furthermore, though not statistically significant, an interaction between exercise and music was observed by the analysis of variance. It is thus suggested that the exercise-induced ascendency in sympathetic nerve activity was enhanced by music. On the other hand, effects of music itself seem faint, as pre-exercise levels of the measurements were not significantly different between with and without music, agreeing with no significant effects of music by the analysis of variance. Further study on a larger number of subjects will be necessary to confirm the findings of the present study.

Davis and Thaut (1989) observed that when preferred music decreases anxiety and brings
about relaxation, heart rate, vascular constriction, peripheral skin temperature, and muscle activity are stimulated rather than depressed. Shimomura et al. (1997) measured electroencephalogram, respiration, and pulse rate after listening to preferred music and found that listening to music resulted in excitation of the sympathetic nervous system, as indicated by an increase in respiration and pulse rate, regardless of the type of music (stimulating or calming). In the present study, we also used music according to subjects’ preferences. Our results showed that the higher the sympathetic nerve activity was before exercise, the higher the LF/HF was after exercise, regardless of whether or not the subject listened to music, indicated by significant correlations between LF/HF before and after exercise. It thus appeared that after exercise in which sympathetic nerve activity is dominant, preferred music acts in synchrony with the activated physical response to further promote the response and increase sympathetic nerve activity, both for just listening to music and for using the body sonic system.

On the other hand, the above previous researches suggesting that music affects the parasympathetic nervous system were based on listening to music after resting. It is possible that maintaining a resting state for a certain length of time brings about a biological response in which the parasympathetic nerves tend to dominate in association with a calming of mood and that subsequently listening to music further promotes the response, thereby increasing parasympathetic nerve activity. It appears that music that is in synchrony with a person’s mood at the time promotes a psychological response that leads to physiological changes regardless of whether the person is in an activated or calm state. The fact that a previous study showed no difference in LF/HF for music, bird song, and mechanical sounds produced with a synthesizer as sound stimuli suggested that the sympathetic nervous system was not affected by sound (Yanagihashi et al. 1997). This was probably because the sound stimuli were presented for only a short period (5 min) and because sound, unlike music, does not give rise to responses that involve emotions, such as memories and images.

We were unable to clarify the relationship between physiological changes and psychological changes in our study, but it has been suggested that mediation by music in combined relaxation programs with physical activity leads to psychological activation (Urakawa 2003). By the same principle, the fact that music did not have a calming effect on psychophysical activation as a result of physical activity was thought to be due to the effect of promotion of emotional responses on physiological changes. As people become increasingly health consciousness, more importance is being placed on exercise. Combining exercise with music is not only enjoyable because of its effects on mood but also promotes physiological excitation, thereby increasing physical activation.

Further work is needed to investigate subjects, measurement indicators, and experimental conditions to clarify the relationship between physiological changes and emotional responses produced by music. Heart rates and other cardiac variables should have been measured during exercise to clarify physiological responses more in details. Effects of types of music should be examined by controlling for rhythm and tempo in a further study.

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