THE JOURNAL OF ALTERNATIVE AND COMPLEMENTARY MEDICINE
Volume 15, Number 1, 2009, pp. 53–57

DOI: 10.1089/acm.2008.0243

# Effects of Music and Essential Oil Inhalation on Cardiac Autonomic Balance in Healthy Individuals

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## Abstract

***Objective:*** The purpose of the present study was to investigate the effect of listening to soft music or inhaling *Citrus bergamia* aroma on autonomic nervous system activity in young healthy individuals.
***Study design, location, and subjects:*** This single-institution study was an open-label randomized controlled trial carried out on 114 healthy undergraduate students at a university located in south Taiwan.
***Intervention:*** Participants were randomly allocated to one of four study groups including (1) a music group, (2) an aroma group, (3) a combined music and aroma group, and (4) a control group. Participants in the music group were asked to listen to preselected soft music for 15 minutes, and those in the aroma group were asked to inhale *Citrus bergamia* essential oil vapor generated from an ultrasonic atomizer for 15 minutes.
***Outcome measure:*** The outcome measure involved heart rate variability (HRV) indices measured before and after the intervention. The low frequency (LF) and high frequency (HF) components of the HRV were used to quantify modulation of the sympathetic and parasympathetic branches of the autonomic nervous system.
***Results:*** The percentage changes of normalized LF ($p = 0.003$), normalized HF ($p = 0.001$), and the ratio of LF to HF ($p < 0.001$) were significantly different among the four groups. Tukey's post hoc analysis revealed that the percentage change of normalized LF and HF were significantly different between the control group and the music group. For the percentage change of the ratio of LF to HF, the negative change in the music group, the aroma group, and the combined group was significantly different from that of the increase in the control group. In addition, no significant differences were found in the percentage changes in systolic blood pressure, diastolic blood pressure, and mean heart rate in the four groups.
***Conclusions:*** Listening to soft music and inhaling *Citrus bergamia* essential oil was found to be an effective method of relaxation, as indicated by a shift of the autonomic balance toward parasympathetic activity in young healthy individuals.

## Introduction

Psychological stress has been found to relate to adverse health outcomes[1] and has been implicated in the process of wound healing, the development of infectious diseases, and survival in certain chronic conditions, such as cardiovascular disease and cancer.[2] Various stress-lowering techniques such as music[3,4] and aromatherapy[5,6] have been reported and reviewed.[7,8]

In the present study, music therapy is defined as the approach to achieve relaxation by listening to music. It is the ability to listen to music as a means to alter one's mood or to promote homeostasis.[9] A meta-analysis of 22 quantitative studies reported that music alone and music-assisted relaxation techniques significantly decreased arousal due to stress with a mean effect size of 0.67 (95% confidence interval [CI] 0.56, 0.78).[7] The study also concluded that music selected on the basis of research is the most effective and that musicians, females, and those under 18 years of age respond more to music-assisted relaxation techniques when under stress.

Different types of music affect the cardiovascular and respiratory systems in different ways. Bernardi and colleagues found that ventilation, blood pressure, and heart rate increased and baroreflex decreased with music of fast tempo and simple rhythmic structures. Conversely, slow or meditative music was found to induce a relaxing effect. Moreover, by alternating fast and slower rhythms and pauses, sympathetic activity could be reduced, which might be useful in the management of cardiovascular disease.[10]

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Physiological and psychological effects of aroma have been recognized in folk medicine for a long time.[8,11] Although the exact cellular mechanism of action of ambient odors in inducing emotional changes is unknown, studies on inhalation of lavender essential oil have suggested that the effects act via the limbic system, particularly through enhancing the effects of gamma-aminobutyric acid in the amygdala. In addition, the major volatile constituent of lavender, linalool, can inhibit acetylcholine release and is thought to act as a sedative.[12] Of the various essential oils, citrus and lavender fragrances have been widely studied for their mood-enhancing and relaxation properties.[13–16] The essential oil of *Citrus bergamia,* a member of the Rutaceae family, bergamot oil, is primarily produced in Calabria, in southern Italy. The essential oil, yellow-green in color, is obtained from the cold-pressed peels of the fruit and consists of approximately 80 volatile constituents such as limonene, linalool, and linalyl acetate, and nonvolatile constituents such as bergamottin, citroptene, and bergaptene.[17] A recent study on mice found that the inhalation of lemon oil vapor provided an anti-stress effect in experimentally induced stress conditions. The authors further postulated that lemon oil inhalation could reduce distress through the suppression of dopamine activity via enhanced serotonergic neurons.[18]

In recent years, heart rate variability (HRV) has been used as an objective physiological indicator of the activity of the cardiac autonomic nervous system. It has been used to represent physiological responses in studies of music therapy[19] and aromatherapy.[20] Specifically, it provides a noninvasive probe of the balance of the sympathetic and parasympathetic (vagal) divisions of the autonomic nervous system. This is achieved through the analysis of temporal patterns in the variations that occur in the interval from one heart beat to the next (R–R interval). In addition, such time domain measures can be converted into frequency domain (power spectral density) measures by fast Fourier transformation. The resulting frequency domain measures can provide an estimation of the amount of variation at specific frequencies, which can then be used to quantify sympathetic and parasympathetic activity of the nervous system. A comprehensive review of HRV and its measurement has been provided by a joint task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology.[21]

The objective of the present study was to investigate whether listening to soft music or inhaling *Citrus bergamia* oil would affect autonomic nervous system activity in young healthy individuals. We also investigated whether there was any synergistic effect when the two interventions were applied together.

## Materials and Methods

### *Participants*

Healthy undergraduate students between the ages of 18 and 25 years were recruited by flyers distributed on campus at a university in south Taiwan. The exclusion criteria included hearing impairment, olfactory impairment, pregnancy, and history of asthma. After informed consent was obtained from each of the participants, they were randomly allocated to one of four groups, as follows: (1) a music group; (2) an aroma group; (3) a combined music and aroma group; and (4) a control group.

### *Study protocols*

All tests was conducted individually, with the participant seated in a semi-reclining chair in a well-lit (58 lux), quiet, air-conditioned (24° ± 1°) room of 21.3 $m^2$ designated for the study. All tests were performed between 0830 and 1230 hours to minimize circadian variation of the autonomic nervous system. Only one participant was studied each time to avoid mutual distraction during testing. The room was allowed to ventilate with fresh air for at least 15 minutes between participants.

We used a pretest–post-test design to compare the differences in blood pressure and HRV indices. After pretest measurements were taken, participants were exposed to one of four conditions (music, aroma, combined music and aroma, or control) for 15 minutes, after which post-test measurements were recorded.

Each participant in the music group was provided with an open-air type headphone (Sennheiser HD515) for listening to five preselected pieces of music from Bandari's *Sunny Bay* compact disc (Jingo Records, ISSN: JCD 02030) for 15 minutes. The music was played at a volume of 80–90 decibels. Bandari is a New Age style band that is popular in China and Taiwan (http://world.bandari.net/).

Participants in the aroma group were instructed to inhale the mist of *Citrus bergamia* essential oil (First Chemical Works, Taipei, Taiwan) over a 15-minute period. The essential oil was diluted 1:75 with distilled water, and the mist was dispensed through an ultrasonic atomizer (SHIMED Model No. 028809). The atomizer was placed approximately 60 cm away from the participant. Oil of bergamot is an extract from the rind of bergamot orange (*Citrus aurantium* spp. *bergamia*) that has a pleasant, refreshing scent.[22] It gives the characteristic flavor of Earl Grey tea.[23] Bergamot oil contains bergapten (5-methoxypsoralen), bergamottin (5-geranyloxypsoralen), and citropten (5,7-dimethoxycoumarin).[23,24]

The combined music and aroma participants were given both music and essential oil for 15 minutes.

The control group participants were asked to rest quietly on the semi-reclining chair for 15 minutes.

HRV measured with a handheld HRV device (CheckMyHeart version 3.0; DailyCare BioMedical Inc., Fremont, CA) fitted with foam electrodes (Kendall Medi-Trace 200). Five (5)–minute segments of electrocardiogram were obtained and power spectra were automatically created via a fast Fourier transformation. The resulting spectrum was integrated, and areas associated with discrete frequency bands were obtained from the output of the device.

### *HRV data analysis*

We used the time domain HRV index of SDNN (Standard Deviation of all Normal to Normal intervals) to estimate the overall modulation of autonomic nervous system function, and to reflect its total variability. For the frequency domain HRV indices, power spectra within the 0.04–0.15 Hz range were considered low frequency components (LF), whereas frequencies of 0.15–0.4 Hz were defined as high frequency components (HF). The power content of the HF component corresponds to respiratory sinus arrhythmia and is modulated solely by the parasympathetic nervous system. The power content in the LF component corresponds to blood pressure oscillations occurring around 0.1 Hz and is modu-

Table 1. Characteristics of the Study Sample ($N = 114$)

| *Variables* | *Control* (n = *26*) | *Music group* (n = *30*) | *Aroma group* (n = *28*) | *Combined group* (n = *30*) | p-*value* |
|---|---|---|---|---|---|
| Female | 22 (85%) | 26 (87%) | 25 (89%) | 27 (90%) | 0.942 |
| Age (years) | 20.3 ± 1.5 | 20.1 ± 1.5 | 20.4 ± 1.6 | 20.4 ± 1.4 | 0.849 |
| Weight (kg) | 59.0 ± 12.2 | 58.1 ± 11.8 | 59.6 ± 10.3 | 60.2 ± 15.5 | 0.925 |
| Height (cm) | 163.3 ± 7.1 | 162.6 ± 6.9 | 163.4 ± 7.4 | 162.5 ± 8.1 | 0.958 |
| BMI ($kg/m^2$) | 22.1 ± 3.8 | 21.9 ± 3.8 | 22.3 ± 3.1 | 22.7 ± 5.0 | 0.885 |

Values are mean ± standard deviation for age, weight, height, and BMI (body–mass index).

lated jointly by the sympathetic and parasympathetic nervous systems.[25] The ratio of LF to HF (LF/HF) was adopted to determine the predominance of cardiac sympathetic nervous activity. We did not calculate the power of the very low frequency component (0–0.04 Hz) because it was found to be unreliable over short recording periods.[21] High frequency and low frequency were also calculated in normalized units (nu) that represented the relative values of each power component in proportion to the total power minus the very low frequency component. Normalized HF and normalized LF are indices of autonomic control that are independent of total spectral power of HRV.[21,26] Normalized HRV indices often have much smaller coefficients of variation when evaluated in reproducibility studies.[27]

### *Statistical analysis*

Continuous variables were expressed as mean ± standard deviation. One-way analysis of variance (ANOVA) was used for comparing characteristics of the participants other than sex, for which Fisher's exact test was used. Percentage changes were calculated for each outcome as: [(post-test value − pretest value) × 100/pretest value] to adjust for differences in pretest values. One-way ANOVA was used for comparing percentage changes, and post-hoc analyses using the Tukey test were used to compare differences among the four groups when the overall effect was statistically significant. Values of $p < 0.05$ were considered statistically significant. All statistical analyses were performed with SPSS for Windows, version 12.0 (SPSS, Chicago, IL).

## Results

The mean age of the 114 participants was 20.3 ± 1.5 years. There were no significant differences in the sex distribution, age, weight, height, and body–mass index (BMI) in the four groups (Table 1). Both resting (control group) and the three interventions led to a decrease in systolic blood pressure, diastolic blood pressure, and mean heart rate that ranged from 5% to 9% (Table 2). However, no statistically significant group differences were found in the percentage changes for the four groups in these three parameters.

For measures of heart rate variability, no statistically significant group differences were found in the percentage

Table 2. Mean Percentage Change in Blood Pressure, Heart Rate, and Heart Rate Variability (HRV) Indices between Four Groups ($N = 114$)

| *Group* | *Control* (n = *26*) | *Music* (n = *30*) | *Aroma* (n = *28*) | *Combined* (n = *30*) | *ANOVA* p-*value* |
|---|---|---|---|---|---|
| Blood pressure | | | | | |
| ΔSBP (%) | −6.28 ± 5.74 | −5.72 ± 6.44 | −6.38 ± 6.50 | −5.09 ± 6.81 | 0.863 |
| ΔDBP (%) | −6.75 ± 10.46 | −7.39 ± 7.12 | −9.03 ± 10.85 | −6.02 ± 7.91 | 0.640 |
| Heart rate | | | | | |
| ΔMHR (%) | −6.67 ± 6.22 | −5.27 ± 6.07 | −7.19 ± 5.70 | −4.98 ± 6.18 | 0.443 |
| Heart Rate variability | | | | | |
| Time domain | | | | | |
| ΔSDNN (%) | 26.28 ± 31.06 | 20.20 ± 31.56 | 28.08 ± 52.56 | 17.31 ± 33.75 | 0.681 |
| Frequency domain | | | | | |
| ΔTP (%) | 67.37 ± 75.65 | 51.45 ± 79.06 | 84.36 ± 223.90 | 44.23 ± 88.46 | 0.663 |
| ΔLF (%) | 83.25 ± 85.23 | 46.80 ± 132.69 | 58.77 ± 82.71 | 43.66 ± 93.15 | 0.464 |
| ΔHF (%) | 67.38 ± 85.14 | 164.23 ± 313.58 | 113.38 ± 134.41 | 79.81 ± 133.74 | 0.223 |
| ΔnLF (%)[a] | 6.04 ± $26.52^{1}$ | −17.00 ± $23.36^{2}$ | −6.66 ± $21.70^{1,2}$ | −9.69 ± $19.34^{1,2}$ | 0.003 |
| ΔnHF (%)[a] | −4.50 ± $14.97^{1}$ | 27.89 ± $37.38^{2}$ | 15.78 ± $29.48^{1,2}$ | 14.31 ± $31.27^{1,2}$ | 0.001 |
| ΔLF/HF (%)[a] | 16.03 ± $42.60^{1}$ | −27.90 ± $32.20^{2}$ | −11.89 ± $37.54^{2}$ | −13.97 ± $34.75^{2}$ | <0.001 |

[a]Means with different superscript numbers in the same row are significantly different at $p < 0.05$.

Values are mean ± standard deviation.

ANOVA, analysis of variance; SBP, systolic blood pressure; DBP, diastolic blood pressure; MHR, mean heart rate; SDNN, standard deviation of all normal to normal intervals; TP, total power; LF, low frequency power; HF, high frequency power; nLF, normalized low frequency; nHF, normalized high frequency; LF/HF, ratio of LF to HF.

change of time domain index SDNN (Table 2). For frequency domain indices, the percentage changes of normalized LF ($p = 0.003$), normalized HF ($p = 0.001$), and ratio of LF to HF ($p < 0.001$) were significantly different among the four groups (Table 2). Post hoc analysis revealed significant differences in the percentage change of normalized LF and HF between the control group and music group. There were no significant differences between the control group and the aroma group or between the control group and the combined group. Participants in the control group showed an increase in normalized LF and a decrease in normalized HF, whereas those in the other three groups showed an opposite change. There were no significant differences in the music group, the aroma group, and the combined group in terms of normalized LF and normalized HF. For the percentage change in the LF to HF ratio, participants in the control group showed a positive change, whereas the other three groups showed negative changes, and all three groups were significantly different from the control group. There were no statistical differences among the music group, the aroma group, and the combined group in the percentage change in the LF/HF ratio.

## Discussion

This randomized control trial evaluated whether listening to soft music, inhaling an essential oil, or exposure to both interventions for a 15-minute session could affect cardiac autonomic balance in young healthy individuals. With heart rate variability as a noninvasive measure of the activity of the sympathetic and parasympathetic nervous system, the results showed that listening to soft music, as compared to simply resting, could shift the autonomic balance toward parasympathetic predominance. The mean percentage change in the LF/HF ratio increased 16% in the control group, whereas in the other three experimental groups it decreased significantly, from 12% in the aroma group to 28% in the music group.

There were no significant differences among the three experimental groups in the mean percentage change of normalized LF, normalized HF, and the LF/HF ratio, indicating that the parasympathetic-enhancing effect of listening to soft music and inhaling *C. bergamia* essential oil were similar, and there was no synergistic effect when the two interventions were applied at the same time. It is possible that the homeostatic control of the autonomic nervous system[28] limits the extent of shift of the autonomic balance with the duration of the intervention used in the present study. However, whether a synergistic effect can occur with a shorter duration of music or aroma intervention will require further study.

Our findings are consistent with those from previous studies using lavender essential oil. Duan and colleagues examined the HRV in 10 healthy young women exposed to lavender odor in a crossover randomized controlled trial.[15] They reported that lavender use significantly increased nHF with simultaneous reductions in the LF to HF ratios. Their results indicated that lavender odor could promote relaxation by reducing sympathetic activity while augmenting parasympathetic activity in healthy adults. Both lavender and *C. bergamia* essential oils contain linalyl acetate as one of their major components.[29] An animal study found that linalyl acetate could relax vascular smooth muscle through myosin light chain dephosphorylation and activation of the nitric oxide and cyclic guanosine monophosphate pathway.[30]

Systolic blood pressure, diastolic blood pressure, and mean heart rate showed a 5%–9% decrease with just plain resting or with any of the three interventions. There were no statistical differences between the four groups in these three parameters, indicating that exposure to soft music or essential oil did not induce an effect beyond that already achieved by plain resting. These results were consistent with a recent randomized controlled trial on aromatherapy in which relaxant odor (lavender), stimulant odor (lemon), and no-odor control (water) did not alter heart rate or blood pressure.[31] Another study comparing the effects of water, lavender, and rosemary scent following an anxiety-provoking task reported that mood ratings differed by scent condition but no differences in heart rate were observed based on scent exposure.[32] In addition, no significant differences in heart rate and blood pressure between lavender inhalation and control were found in a crossover randomized controlled trial of 10 healthy young women.[15]

Several limitations of the present study deserve mention. Since only one music CD and one type of essential oil were used in the study, the relaxation effect of the intervention could not be generalized to other music pieces or essential oils. It would be of interest to compare the effects using music from other New Age musicians or from other genres such as music of the Baroque period, and effects of other common essential oils such as that derived from *Lavandula angustifolium*.

Bergamot oil is a well-known UVA-induced photosensitizer with a strong phototoxic effect because it contains furocoumarins, primarily bergapten (5-methoxypsoralen [5-MPO]).[22,33] To avoid any potential health hazard, exposure to sunlight or UVA radiation from tanning salons must be avoided after topical application of bergamot essential oil. A bergapten-free topical form of *C. bergamia* essential oil can be used instead. When *C. bergamia* is delivered via inhalation, however, it is not associated with a phototoxic effect.

## Conclusions

In summary, we conducted an open-label randomized controlled trial on young healthy adults to investigate the effect of listening to soft music and inhaling the aroma from *Citrus bergamia* essential oil on autonomic balance. The results provided support for the relaxation effect of music and aroma, as indicated by a shift of the autonomic balance toward parasympathetic predominance. Listening to soft music and inhalation of essential oil[34] may provide a relatively simple, safe, and effective method of relaxation.

## Disclosure Statement

No competing financial interests exist.

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