Full-Length Article

Low Frequency Music Slows Heart Rate and Decreases Sympathetic Activity

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Abstract

Objectives: Increasing blood pressure (BP) increases the risk of developing cardiovascular disease (CVD). Lower frequency music may lower BP and heart rate (HR), therefore, decreases the CVD risk.

Methods: Participants were 16 high BP individuals aged 20 to 50 years. The protocol consisted of 2 visits (experimental & control). Music was tuned between 440 Hz and 432 Hz, and the frequencies changed every 10 minutes. HR variability, diastolic function, oxytocin, and amylase were recorded at each phase. An (ANOVA) was used to examine the effects of music.

Results: Mental arithmetic significantly increased BP and HR (all ps<0.01). There were significant differences between the stress condition and all other conditions, all p's < .02. There was a significant main effect for Music Order, F (1, 6) = 6.23, p = .047, ηp2= .51, β = .55. Participants had lower HR listening to 432 Hz music (M = -7.20, se = 2.47) than 440 Hz music (M = -5.33, se = 2.71), t(7) = 2.53, p = .04, d ' = .41.

Conclusion: Listening to low frequency music has cardiovascular benefits including slowing heart rate and promoting relaxation. Further study is needed to determine the underlying mechanisms of music induced beneficial effects.

Keywords: ***blood pressure; heart rate; music frequency; oxytocin; amylase;***

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Introduction

Humankind has known that music is efficacious in healing and this knowledge has been recorded as far back as ancient Greece. Francis Bacon[1] observed that the Greeks had properly unified music and medicine under the same god (Apollo) for "the task of medicine is nothing other than tuning that strange harp that is the human body and restoring its harmony." Modern science has confirmed that music can have a strong influence on emotional arousal and on an individual's stress level [1-3]. Today, physicians, music therapists, psychologists, and other health providers use music to treat a variety of conditions including cardio-vascular diseases[4-7]; pain management[8-11]; and preoperative anxiety[12]. Other studies have looked at how listening or not listening to music effects test performance by undergraduates. The results of these studies have been largely contradictory, some finding music enhances performance, has no influence, and others suggest it has a negative effect[13-16]. However, the underlying scientific bases for the connections between music and body and music and anxiety are not well-understood[17-19]. Earlier research has demonstrated the brain regions that process music[19, 20], yet knowing how the physiology works is not the same as knowing why it works. To access the why, one must examine subjects as not just biological creatures, but also as whole persons with distinctive physiological, psychological and cultural differences[21].

Changes in music frequency can induce cardiovascular responses (e.g., blood pressure, heart rate)[22]. Music has been known to synchronize inherent cardiac rhythms, implying it can be used to control heart rate[23-24]. Music

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can also affect an individual's emotional state or mood, which also induces changes to the autonomic nervous system (ANS) [i.e., sympathetic (SNS) and parasympathetic nervous system (PNS)[24-26]. Previous work has linked music to the ANS balance[25, 27-31]. Since SNS arousal and PNS withdrawal increases the likelihood of the development of cardiovascular disease (CVD), it is no surprise that music may be cardio-protective.

Listening to music is a catalyst for stress reduction. Hence, music can be used as medicine in stressful circumstances[32]. Although music has been extensively used in-patient care, little is known about its relationship to cardiovascular health. White, et al.,[33] indicated that relaxing music could induce a relaxation response, triggering the PNS arousal and in turn, lowering heart rate (HR). It has also been suggested that people may respond differently to different music stimuli depending on their age, gender, and cultural background. We believe that if a stronger effort was made to improve the quality of relaxing music, we stand the chance of lowering blood pressure in individuals at high risk of cardiovascular disease such as hypertensive patients. This is because most people enjoy and can effortlessly adhere to music, especially if a health benefit can be demonstrated.

Another possible underlying mechanism of music effect could be oxytocin, which is a neuro-hormone with bonding and relaxing effects[34]. Studies have shown that oxytocin does increase while participating in some kind of music stimulus[35-37], [38-40]. However, the relationship between music and oxytocin has not been systematically examined in individuals with blood pressure elevation. This study was conducted to start filling in these gaps.

We hypothesize that music will reduce sympathetic arousal, enhance parasympathetic nervous system activities, and increase Oxytocin secretion.

Methods

Participants were 16 volunteer adults between the ages of 25-50; 55% were females. Participants were separated in two different groups. Group 1 had eight participants 62% female. Group 2 also had eight participants 55% female. Recruited participants were screened based on the study's criteria. All participants had to be between the ages of 25-50 and have BP readings of 120 -139 mmHg for systolic and 80-89 mmHg for diastolic; have no history of CVD; not using other stress management strategies including other meditation techniques, methods of relaxation; or participating in any other organized stress management programs in the past 12 weeks. Potential participants were excluded from the study if they had a healthy normal BP (systolic < 120 mmHg and diastolic < 79 mmHg), were currently smoking, had a psychiatric disorder, endocrine systemic disease (e.g., thyroid disorders, diabetes mellitus), CVD (e.g., congestive heart failure, coronary artery disease, cardiomyopathies, tachyarrhythmia, previous cardiac surgery), chronic pulmonary and renal disease and certain medications that could not be discontinued and that could influence the hemodynamic response to stress. All participants signed an informed consent and had full knowledge of all procedures before any testing took place.

Further, the music used in this study was recorded using two different tuning methods. Contemporary musicians tune their instruments to Concert A, a pitch equivalent to 440 Hz. In earlier times (pre-1939), Concert A pitch was 432. Both frequencies were used at different time intervals in the same piece of music to observe any physiological health benefits.

Procedures:

Participants had two visits (experimental & control). Each visit started with 20 minutes of baseline (participant watched a movie during this time) and 10 minutes of a stressor exposure (e.g., mental arithmetic). At the start of testing, participants sat in a comfortable chair. The subjects were then fitted with equipment for recording BP and heart rate (HR) (Dinamap Model 1846 SX, Critikon Inc., *Tampa, FL, USA).* The elbow of the non-dominant arm was stabilized with an arm board; a 21-gauge butterfly needle was inserted into the antecubital vein, and a three-way plastic stopcock was attached. A catheter was placed in the arm so the participant was only stuck by the needle once. Immediately after the catheter placement, a 5-ml blood sample was drawn, transferred to a 10-ml pre-chilled EDTA tube vacutainer, and maintained on ice. All subsequent blood collection followed this procedure. One milliliter of 0.9% saline was infused at 2–3 min intervals to try to help maintain patency. Blood was centrifuged at 4 °C and plasma collected and stored at – 80 °C until analysis.

After the initial blood draw, the participant was given standardized instructions to relax as completely as possible for 20 minutes. Participants listened to one piece of music, which contained two different frequencies for 30 minutes, only during the experimental visit. Participants were randomly exposed to either schedule A or B music regimen. In schedule A, the music sequence started with 440 Hz then changed to 432 Hz then back to 440 Hz. In schedule B, the music sequence started with 432 Hz then changed to 440 Hz then back to 432 Hz. In both schedules A and B, each frequency lasted 10 min. There was no music for the control visit. The participants watched a movie instead. All participants were exposed to mental arithmetic during the last 10 minutes of the protocol. The visit order of experimental and controls were randomly changed for different study participants.

Hemodynamic measurements (that is, SBP, DBP, and HR) were obtained every 5 min (readings at minutes 5, 10, 15, and 20 were averaged and subsequently used as baseline values). Blood samples were drawn at minute 20, 60, and 70 during both visits.

Music

The pre-recorded music piece was "Galactic Sailing" was composed specifically for this study. The piece of music, written with a tempo of approximately 56 beats per minute (bpm, close to the ideal resting HR of 60 bpm), was designed to promote a meditative state. Long tones (drones) were initially used to create this effect. In addition to this, suspension tones were used to better induce a meditative state for the test subject. The music frequencies alternate every 10 minutes from 432 Hz to 440 Hz.

Pulsed Doppler was used to record the mitral inflow to derive indices of LV filling[22-24]. The tracing of five consecutive cardiac cycles having the highest velocity in E will be analyzed. The following parameters were examined: peak velocity of E; peak velocity of A; their ratio (E/A). Inter-reader variability of Doppler was maintained below 10%.

Tissue Doppler was obtained by using apical 4-chamber view for evaluating the mitral valve annulus [25]. The 1-2 mm sample volume was consistently placed at the lateral mitral annular region. Peak spectral longitudinal contraction (Sm) which is a measure of systolic function, initial (E'), and final (A'), diastolic velocities for 5 consecutive beats was analyzed, and E'/A' ratio was calculated. The reproducibility of both acquiring and measuring E' and A' has been determined in recordings obtained from 10 subjects. The intra-observer and inter-observer differences in parameter estimates were less than 10%. Pulsed Doppler and tissue Doppler E wave were combined to generate the noninvasive filling pressure E/E', which is highly correlated with invasively determined LV end diastolic pressure and strongly predicts survival after a cardiac event[21, 26]

Statistics

The initial order of music exposure was randomized and balanced within race-sex groups to control for order effects. Repeated- measures analysis of variance (ANOVA) with two repeated measures [Music 432 Hz vs. no music and time (baseline, manipulation, and recovery)] was used to examine the effects of relaxing music on the physiological parameters and oxytocin. A repeated-measures ANOVA with one repeated measure (Music 440 Hz vs no music) was used to examine test performance.

Results

Systolic Blood Pressure

There was no significant main effect for "Music or Stress," $F (4, 20) = 1.35$, $p = .29$, $\eta p2= .21$, $\beta = .34$. There was no significant main effect for Music Order, $F (1, 5) = .68$, $p = .45$, $\eta p2= .12$, $\beta = .10$. No significant interaction was found between "Music or Stress" and Music Order, $F (4, 20) = .26$, $p = .90$, $\eta p2= .05$, $\beta = .10$.

Heart Rate

There was a significant main effect for "Music or Stress," $F (3, 18) = 11.05$, $p < .001$, $\eta p2= .65$, $\beta = .99$. Pairwise comparisons show significant differences between the stress condition and all other conditions, all p's < .02.

There was a significant main effect for Music Order, $F (1, 6) = 6.23$, $p = .047$, $\eta p2= .51$, $\beta = .55$. Participants in the 432Hz first condition showed greater overall reduction in HR (M = -8.46, se = 2.60) than the 440 Hz first condition (M = .70, se = 2.60).

There was no significant interaction between "Music or Stress" and Music Order, $F (3, 18) = .80$, $p = .51$, $\eta p2= .12$, $\beta = .19$.

T-test comparisons showed participants had lower heart rates listening to 432 Hz music (M = -7.20, se = 2.47) than 440 Hz music (M = -5.33, se = 2.71), $t(7) = 2.53$, $p = .04$, d ' = .41.

Heart Rate Variability

There was no significant main effect for LF, HF, LF/HF and RMSSD. There was an interaction between Music and Stress. LF/HF was marginally lower during music as indicated by $F (2, 10) = 3.47$, $p = .07$, $\eta p2= .41$, $\beta = .51$.

Diastolic Function

There was no E/A main effect for music or stress, $F (4, 24) = .33$, $p = .85$, $\eta p2= .05$, $\beta = .11$.

There was no significant changes in E/A ratio for music frequency order as shown by $F (1, 6) = .74$, $p = .42$, $\eta p2= .11$, $\beta = .11$.

E/e' showed no significant changes between music or stress as shown by $F (4, 20) = 2.10$, $p = .12$, $\eta p2= .30$, $\beta = .52$. There was no significances for E/e' in music frequency order as shown $F (4, 20) = 1.56$, $p = .23$, $\eta p2= .24$, $\beta = .40$.

Hormones

A one-way ANOVA revealed higher no significant differences in oxytocin levels according to group 1 as shown by $F(2, 21) = .64$, $p = .54$. The mean value of amylase was lower in music when compared to stress and rest conditions. These differences did not reach statistical significance (see figure 1).

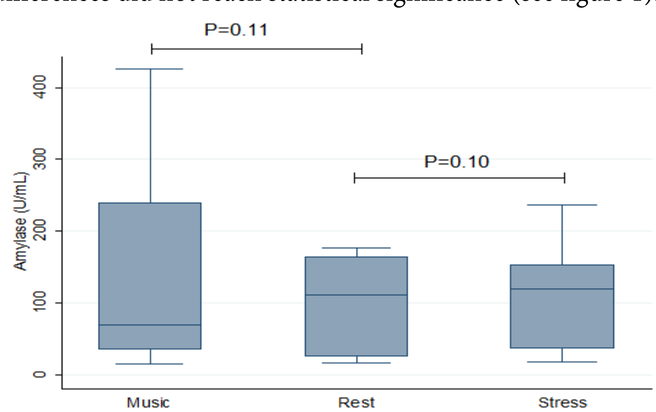

Figure 1: *Amylase Changes*

Discussion

The main finding of our study is that low frequency music at 432 Hz was associated with a decrease in heart rate while no such effect was observed with higher frequency music at 440 Hz, suggesting that modern music tuning frequency have lesser benefit on cardiovascular functioning when compared to the older music turning frequency. This finding confirms previous work from Kreutz, et al.,[41] who consistently demonstrated the health benefits of music.

Like Nakajima, et al.,[30] and Gabel et al.,[31] we propose that the autonomic nervous system plays an important role in the music effect. Indeed, examining heart rate variability, which probes the ANS during music intervention, we demonstrate that the LF/HF was lower during music intervention signifying the possible attenuation of the sympathetic nervous system during music condition. One could evoke that the lower LF/HF was due to the arousal of the parasympathetic nervous system. We believe this is not the case because the parasympathetic nervous system indices remain unchanged. Particularly, HF was similar between resting and music conditions. Although not statistically significant, we found that salivary alpha amylase, which is an index of sympathetic nervous system (SNS) activity decreased while listening to music and increased during stress, suggesting our music intervention was effective into alleviating stress induced sympathetic arousal.

The mechanism, by which music modulates blood pressure remains unclear. Most studies in music link decreased blood pressure to the slowing down of the breathing rate, which subsequently activates of the parasympathetic nervous system and lowers the baroreflex sensitivity[42-43]. Additionally, music may induce pleasant emotions that elicit relaxation. Herein, we found no significant blood pressure differences between resting and music listening conditions. We believe this has to do with the fact that our study participants were already sitting quietly and enjoying a videogame of their choice during resting period. The pressure reducing effect of music was not strong enough to elicit a significant blood pressure decline in already relaxing individuals. Nevertheless, there was a trend toward blood pressure decrease, which together with the observed slow heart rate points to a potential cardiovascular health benefit; however, more research is needed to explore the longitudinal effects. Even a small reduction of the systolic blood pressure has been previously shown to significantly reduce coronary artery disease, stroke, and all-cause mortality[44-46]. Therefore, it is tempting to use music as an alternative way to control BP and prevent cardiovascular disease manifestation. Unfortunately, the cardiovascular effects of music in the context of various types of music (e.g., own choice, prescribed frequency tailored) have not been completely explored. Hence, no clear recommendations exist on how music interventions should be administered to be effective in the treatment of high blood pressure.

To the best of our knowledge, this is the first study to examine the effect of music on diastolic function of hypertensive patients. Contrary to our previously reported decrease of diastolic function during stress[47], we report that no meaningful change in heart filling and relaxation was observed during music. Our findings show that no significant music effect was observed on diastolic function. Further prospective studies are required to assess the effect of different types of music on hypertensive heart function.

This study had several limitations. The population size was relatively small, which made it difficult to probe the effect of cultural backgrounds on our findings. Larger prospective studies will be designed to address these issues. Some participants reported that it was difficult to stay awake for the duration of the music phase, which might have affected the sympathetic activity. We made sure all participants were reminded to stay awake. We report the acute effects of music and our design would not allow us to probe the lasting effect of music. Nevertheless, this study sets the stage for future studies that may be carried out to characterize music that might have long lasting cardiovascular benefits depending on music preference, frequency, rhythm, intensity and melody.

Conclusion

Listening to music slowed heart rate and promoted relaxation. Further study is needed to demonstrate the lasting beneficial effect of music and its underlying mechanisms.

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Biographical Statements

Gaston K. Kapuku, is a physician scientist with expertise in cardiovascular disease (CVD). As a trained cardiologist he has been concerned by the high prevalence of cardiovascular CVD. He is invested in finding cardioprotective interventions suitable for slowing or reversing the development of CVD. Listening to relaxing musing at appropriate frequency might be a possible way to protect cardiovascular health.

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