National Journal of Physiology, Pharmacy and Pharmacology

RESEARCH ARTICLE

Effect of 6 Hz theta frequency binaural beats on post-exercise heart rate and blood pressure recovery

Mansi Pandey[1], Ajay Kumar Saluja[2], Ruchi Shrivastava[2], Mitesh Sinha[2]

[1]MBBS Student, Birsa Munda Government Medical College, Shahdol, Madhya Pradesh, India, [2]Department of Physiology, Birsa Munda Government Medical College, Shahdol, Madhya Pradesh, India

Correspondence to: Mitesh Sinha, E-mail: miteshphysio70@gmail.com

Received: November 20, 2022; **Accepted:** December 16, 2022

ABSTRACT

Background: Binaural beats are an auditory illusion which causes entrainment of various brain waves in the central nervous system which corresponds to various mind consciousness levels. Six Hz binaural beats have found to be causing entrainment similar to that in relaxation techniques such as meditation. Post-exercise recovery of heart rate is a prognostic indicator of various clinical health. The study investigated the effect of presentation of theta binaural beats on post-exercise recovery of heart rate and blood pressure. **Aims and Objectives:** This study aims to compare the effect of 6 Hz theta frequency binaural beats to placebo music on post-exercise blood pressure and heart rate recovery. **Materials and Methods:** It is an observational cross-sectional study in which subjects were enrolled for two sessions of maximal exercise till 70% VO_2 max which was followed by presentation of either binaural beats or placebo during the relaxation period. Recording of heart rate recovery time (HRT) and heart rate recovery ratio and systolic blood pressure recovery time with systolic blood pressure recovery ratio (SBPR1 and SBPR3) were calculated. All data were analyzed using paired *t*-test. **Results:** Forty subjects participated out of which 25 were male and 15 were female. HRT was significantly decreased in the participants when presented with binaural beats as compared to placebo. No significant difference was seen in blood pressure recovery time. Among the participants, the subjects performing moderate physical activity showed increased fall in heart rate and blood pressure in the 1st and 3rd s measured by the recovery ratio. No significant difference was seen in slight and vigorous physical activity subjects. **Conclusion:** Theta binaural beats presented in post-exercise period hasten the heart rate and blood pressure recovery suggestive of entrainment of theta waves which correspond to brain waves similar to that during relaxation techniques such as meditation probably by increasing sympathetic withdrawal and parasympathetic activation.

KEY WORDS: Binaural Beats; Heart Rate Recovery; Systolic Blood Pressure Recovery Ratio

INTRODUCTION

Binaural beats are a subjectively experienced auditory illusion that is perceived when two pure tone sine waves of similar but different frequencies (under 1500 Hz and <40 Hz apart) are dichotically presented to each ear.[1] For example, if 250 Hz pure tone is presented to the left ear and a 256 Hz pure tone is simultaneously presented to the right ear, then an illusionary binaural beat with a frequency rate of 6 Hz is perceived by the brain.

Access this article online	
Website: www.njppp.com	Quick Response code
DOI: 10.5455/njppp.2023.13.11561202216122022	

The binaural beat induces an interesting effect through which brain activity synchronization similar to perceived beat occurs. This phenomenon is called entrainment.[2] When different pure tones are presented through stereo headphones, neural spikes in cochlea become phase locked to the frequency difference between the two ears. This information

is transmitted through the superior olivary nuclei, reticular formation, thalamus to the primary auditory cortex, and other cortical regions.

In theory, once entrainment has occurred at the level of the brainstem, the evoked neural potentials produced in response to repeated auditory stimuli provide information to the thalamus which then acts to accordingly regulate cortical arousal. Several researches have investigated this effect and have attempted to determine the brain activity entrained by binaural beats.

However, the response of the brain to binaural beats remains debated. Many studies reported that these beats have behavioral effects.[3-6].One of the activities of brain which is important in today's lifestyle is theta waves which is also found during meditation. Theta activity has a frequency range of 4–8 Hz and has been found to be associated with the alertness, attention, orientation, and working memory. General theta and frontal midline theta rhythms have been observed during meditation.[7,8]

Six Hz binaural beat on a 250 Hz carrier tone was found to induce theta activity similar to meditation within 10 min stimulus exposure in quantitative electroencephalography.[9]

Exercise has a well-established acute anxiolytic effect. [10] One study reported that during pre- and post-exercise examination, significant increase in alpha power in EEG was reported with decrease in self-reported anxiety.[11] Another study demonstrated that exercise induced increase in both theta and alpha activities and corresponding reductions in beta power.[12] This exercise-induced change was reported in these studies during post-exercise recovery phase of 20 min. Due to the entrainment phenomenon, the theta frequency binaural beats induced brain activity similar to during meditation should serve to elicit a trophotropic response following increased anxiety during moderate cardiovascular exercise which can be assessed by blood pressure and heart rate recovery post-exercise. Sparse literature is available regarding effect of theta frequency binaural waves on sympathovagal balance and post-exercise recovery. In this study, we want to assess the effect of theta frequency binaural waves on blood pressure and heart rate recovery post-strenuous exercise and compare it with placebo sound.

Aims and Objectives

The aims of the study were as follows:

1. To study the effect of 6 Hz theta frequency binaural beats on post-exercise blood pressure and heart rate recovery
2. To compare the effect of 6 Hz theta frequency binaural beats to placebo music on post-exercise blood pressure and heart rate recovery.

MATERIALS AND METHODS

Design

This was an observational, cross-sectional study.

Proposed Duration of the Study

The study duration was 2 months.

Study Population and Sample Size

Forty healthy participants with the age group of 17–25 were recruited for the study.

Exclusion Criteria

Subjects with high cardiovascular risk, smoking, alcohol usage, prescription medication usage, and history of diagnosed physical or mental illness were excluded from the study.

Experimental Area

A study was conducted at Birsa Munda Government Medical College, Shahdol, in the Department of Physiology having a sound attenuated room with an arm chair whose height can be adjusted to the comfort of each subject.

Acoustic Equipment

The stimulus which was used in this experiment to create binaural beats is created by Gnaural which is an open-source program for auditory binaural beat synthesizer where carrier tone of 250 Hz will be presented to right ear and 256 Hz to left ear to create a binaural beat of 6 Hz. The volume was set at 65–70 dB SPL. It will be connected to Sennheiser HD 4.50 noise cancellation headphones. For placebo carrier, tone of 250 Hz was given.

Study Protocol

1. After obtaining approval from the Institutional Ethical committee, a written informed consent was obtained from all the participants
2. The subjects were provided with a questionnaire regarding their demographic and socioeconomic variables, any history or drug history, and physical activity
3. Two sessions were conducted for each subject where the subjects listened to either 6 Hz binaural waves or placebo. On subjects first visit height, weight will be measured and body mass index (BMI) was calculated
4. The subject was instructed to exercise on treadmill up to 70% of VO_2 max as per American College of Sports Medicine guidelines with a 5 min warm up
5. After the completion of exercise, subject rested in a comfortable arm chair and for 20 min either 6 Hz

binaural beat or placebo was delivered to the subject and blood pressure and pulse was measured continuously using PowerLab of ADI instruments.

Data Analysis

The data were analyzed for distribution of data based on standard normality test. For comparison, paired *t*-test was used. The level of significance will be $P < 0.05$.

Data Confidentiality is Maintained

All statistical analyses were performed using SPSS software.

RESULTS

A total of 40 subjects participated in this study out of which 25 (62.5%) were male and 15 (37.5%) were female. Basic anthropometric analysis of the subject showed no significant difference in age and BMI. Each subject underwent the experiment protocol twice, once with 6 Hz binaural waves and one with placebo which was blinded for the subject. Before the exercise, pre-exercise heart rate and blood pressure were measured. The anthropometric and cardiovascular profile of the participants is given in Table 1.

Target heart rate to achieve 60–80% VO_2 max which is categorized as moderate to moderate- severe exercise by American College of Sports Medicine was calculated using a linear regression formula derived from experimental data from Swain *et al*.[13]

$\%MHR=0.6463 \times \%VO_2 \text{ max} + 37.182.$

Where, % MHR=Percentage of maximum heart rate.

% VO_2=Percentage of maximal oxygen consumption.

Maximum heart rate was calculated from MHR=208- (0.7) age.

The participants exercised till target heart rate was achieved. Peak heart rate and systolic and diastolic blood pressure were measured immediately on the culmination of the exercise. The result is tabulated in Table 2.

After exercise, the participants rested and heard either binaural beats or placebo while blood pressure and heart rate were measured after 1 min of exercise completion followed by measurement at interval of 2 min till blood pressure and heart rate reached back to baseline level. Peak heart rate was noted as HR_0, at 1 min as HR_1, at 3 min as HR_3, and so on. The time for return of heart rate to pre-exercise level from peak heart rate was noted as heart rate recovery time (HRT). Similarly, peak systolic blood pressure was noted as SBP_0, at 1 min as SBP_1, at 3 min as SBP_3, and so on. The time for return of systolic blood pressure to pre-exercise level from peak systolic blood pressure was noted as systolic blood pressure recovery time (SBPT). The changes in heart rate and blood pressure from peak to 3rd min of recovery are shown in Figure 1. Figure shows decrease in heart rate and systolic blood pressure is more in binaural beats as compared to placebo at 1st and 3rd min of recovery.

The ratio of heart rate at HR_1/HR_0 and HR_3/HR_0 was calculated for both sessions to determine the rate of recovery and noted as heart rate recovery ratio (HRR_1 and HRR_3), similarly, ratio of SBP_1/SBP_0 and SBP_3/SBP_0 was noted as systolic blood pressure recovery ratio ($SBPR_1$ and $SBPR_3$). This ratio was chosen for analysis as all the participants reached baseline after 3rd s and the data were consistent in all subjects.

Table 3 shows HRT, HRR_1 and HRR_3, SBPT, and $SBPR_1$ and $SBPR_3$ among male, female, and total participants.

The recovery time of both heart rate and systolic blood pressure was less in all the three groups during exercise with binaural beats as compared to placebo. However, the change was only statistically significant in HRT of males and total participants using the paired t-test. The difference in SBPT in all groups was not statistically significant. HRR_1 and HRR_3 and $SBPR_1$ and $SBPR_3$ in all the groups during both the sessions were not statistically significant.

Table 1: Anthropometric and pre-exercise cardiovascular profile of the participants

Variables	Male (*n*=25)	Female (*n*=15)	Total (*n*=40)
Age (in years)	21±1.08	21.4±1.35	21.15±1.18
Height (in cm)	173.28±4.36	157.93±6.37	167.52±9.10
Weight (in kg)	63.12±6.99	54.53±6.85	59.9±8.04
BMI (kg/m²)	21.05±2.53	21.92±2.93	21.38±2.68
Pre-exercise heart rate (/min)	76.24±10.47	78.07±8.86	76.93±9.82
Pre-exercise SBP (mm/Hg)	121.6±6.87	113.13±7.49	118.43±8.15
Pre-exercise DBP (mm/Hg)	74.04±5.52	73.66±5.06	73.9±5.29

*All data expressed as Mean±Standard Deviation, SBP: Systolic blood pressure, DBP: Diastolic blood pressure

Table 2: Peak heart rate and peak systolic and diastolic blood pressure among the participants

Variables	Male (*n*=25)	Female (*n*=15)	Total (*n*=40)
Peak-exercise heart rate (/min)	153.44±5.43	149.93±5.64	152.13±5.70
Peak-exercise SBP (mm/Hg)	159.56±12.97	142.87±8.90	153.3±14.10
Peak-exercise DBP (mm/Hg)	83.84±10.20	79.6±6.66	82.25±9.17

*All data expressed as Mean±Standard deviation, SBP: Systolic blood pressure, DBP: Diastolic blood pressure

The subjects were enquired about the amount of physical activity performed daily by a physical activity rating. The subjects were divided into four groups on the basis of the rating Group 1 – Light activity, Group 2 – Moderate activity, Group 3 – Moderate severe activity, and Group 4 – Vigorous activity. HRT, SBPT, HRR3 (heart rate ratio at 3rd s post-exercise to peak exercise), and SBPR3 (at 3rd s post-exercise to peak exercise) were analyzed for both the sessions in all groups of various physical activity [Table 4]. The recovery ratio of both heart rate and systolic blood pressure in moderately and moderately severe physical activity group was found to be more and statistically significant.

DISCUSSION

The study investigated the effect of 6 Hz binaural beats in improving the post-exercise recovery response which was measured by heart rate recovery and blood pressure recovery. Post-exercise heart rate recovery has been found to be prognostic indicator of various clinical conditions.[14,15] During moderate-to-severe exercise, heart rate is increased due to deactivation of parasympathetic system and activation of sympathetic system. After exercise, post-exercise adaptation of heart rate and blood pressure occurs due to baroreceptor mechanism and progressive parasympathetic activation and sympathetic deactivation.[16-18]

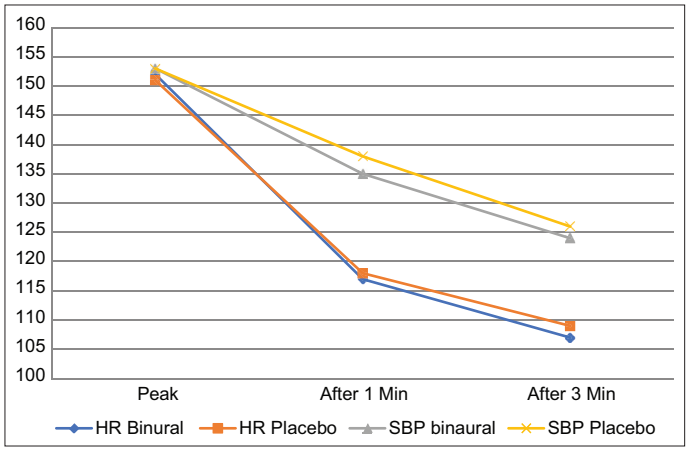

Figure 1: Changes in heart rate and systolic blood pressure during recovery post-exercise while hearing binaural beats and placebo sound

It has been shown that exercise produces anxiolytic effect 10 and decrease in long-term stress[19] when combined with relaxation technique significantly reduces blood pressure in response to any stressor[20] and post-exercise relaxation has found to be positively affected by various relaxation techniques such as music and meditation.

Theta frequency (4–7 Hz) binaural beats facilitate the post-exercise recovery of heart rate and blood pressure. This is attributed to meditation like entrainment of brain waves during presentation of theta wave binaural beats which can be used as a relaxation technique.

In our study, 40 age- and BMI-matched participants were enrolled. The heart rate and blood pressure recovery time were noted and were found that binaural beats were positively correlated to decrease in heart rate and blood pressure post-exercise. Our study showed that HRT was decreased more when binaural beats were presented as compared to the placebo in the subjects. Among males, the result was similar but the decreased was not statistically significant in female participants. This may be attributed to increase in parasympathetic dominance when presented with binaural beats. However, no statistically significant difference was found in SBPT among the participants with binaural beats and placebo.[19]

Similarly, no statistically significant difference was found in HRR_1 and HRR_3 or $SBPR_1$ and $SBPR_3$ among males, females, and total participants. As all the subjects are healthy, parasympathetic activation in response to moderate exercise might not have been significantly affected by type of beats presented.[19]

The subjects were enquired about the amount of physical activity, and on the basis of it, they were classified into four groups. In our study, we found that subjects who were involved in moderate-to-moderate-severe physical activity regularly HRR_1 and HRR_3 or $SBPR_1$ and $SBPR_3$ were significantly decreased faster during binaural beats presentation. Research has shown that during post-exercise heart rate recovery initially,

Table 3: HRT, HRR1 and HRR3, SBPT, and SBPR1 and SBPR3 among male, female, and total participants

Variables	Male			Female			Total		
	Binaural	Placebo	*P*-value	Binaural	Placebo	*P*-value	Binaural	Placebo	*P*-value
HRT	9.28±2.03	10.28±1.94	0.04*	10.2±1.85	11.46±2.26	0.052	9.65±1.96	10.75±2.12	0.009*
SBPT	8.24±4.11	9.56±4.35	0.13	7.4±3.86	8.73±4.31	0.19	7.92±3.99	9.25±4.30	0.078
HRR_1	0.79±0.09	0.79±0.06	0.38	0.74±0.06	0.77±0.05	0.07	0.77±0.09	0.79±0.06	0.16
HRR_3	0.73±0.05	0.72±0.06	0.23	0.70±0.04	0.73±0.04	0.059	0.70±0.06	0.72±0.05	0.08
$SBPR_1$	0.89±0.05	0.92±0.05	0.04*	0.88±0.05	0.88±0.06	0.43	0.89±0.05	0.90±0.06	0.07
$SBPR_3$	0.81±0.05	0.82±0.05	0.21	0.83±0.04	0.82±0.05	0.4	0.81±0.05	0.82±0.05	0.20

*Statistically significant $P<0.05$, HRR1and HRR3: Heart rate ratio at 1st s and 3rd s post-exercise to peak exercise, SBPR1 and SBPR3: Systolic blood pressure ratio at 1st s and 3rd s post-exercise to peak exercise, HRT: Heart rate recovery time, SBPT: Systolic blood pressure recovery time

Table 4: HRT, HRR_3, SBPT, and $SBPR_3$among male, female, and total participants

Variables	HRT	HRR3	SBPT	$SBPR_3$
Grade 1				
Binaural	10.73±0.19	0.73±0.18	7.00±0.15	0.84±0.28
Placebo	11.55±2.46	0.75±0.06	8.36±2.50	0.84±0.03
P-value	0.19	0.18	0.15	0.28
Grade 2				
Binaural	9.94±1.82	0.72±0.05	10.82±5.44	0.73±0.06
Placebo	9.35±4.76	0.82±0.06	10.76±2.13	0.83±0.05
P-value	0.32	0.00*	0.48	0.00*
Grade 3				
Binaural	8.14±0.69	0.72±0.06	9.29±1.25	0.73±0.06
Placebo	7.00±2.83	0.81±0.07	8.29±3.30	0.84±0.04
P-value	0.16	0.01*	0.23	0.00*
Grade 4				
Binaural	8.20±2.68	0.62±0.07	6.40±3.13	0.77±0.03
Placebo	10.60±1.67	0.66±0.04	7.40±3.58	0.77±0.00
P-value	0.06	0.11	0.33	0.44

*Statistically significant $P<0.05$, HRR3: Heart rate ratio at 3rd s post-exercise to peak exercise, SBPR3: Systolic blood pressure ratio at 3rd s post-exercise to peak exercise, HRT: Heart rate recovery time, SBPT: Systolic blood pressure recovery time, HRR_3: Heart rate recovery ratio

both sympathetic withdrawal and parasympathetic activations are involved, while when the heart rate falls below 100 beats per min, parasympathetic activation is predominant.[20] Studies have shown that binaural beats showed more sympathetic withdrawal among fitter subjects doing regular exercise as compared to placebo.[19] Hence, the initial decrease in blood pressure and heart rate depicted by ratio HRR_1, HRR_3, $SBPR_1$, and $SBPR_3$ was affected positively when presented with binaural beats as compared to placebo. Such pattern was not seen in Grade 1 and Grade 4 physical activity subjects.

Limitations

1. The research can be expanded further with more subjects
2. The research can be done in subjects with matched heart rate variability so it is removed as confounding factor in this study
3. Other laboratory stressors can be used to further consolidate the hypothesis.

CONCLUSION

It is evident from the study that 6 Hz binaural beats presentation has positive correlation with decrease in heart rate and blood pressure in post-exercise recovery phase. The effect of binaural beats was more as compared to placebo in heart rate recovery but not significant difference was found in blood pressure recovery. Theta binaural beats enhance the parasympathetic activation and sympathetic withdrawal during post-exercise recovery phase but more effect as compared to placebo is on sympathetic withdrawal so significant recovery is seen in heart rate and blood pressure in the first 3 s post-peak exercise in subjects doing moderate physical activity.

ACKNOWLEDGMENT

Authors gratefully acknowledge ICMR for selecting this project for ICMR-STS 2022.

REFERENCES

1. Draganova R, Ross B, Wollbrink A, Pantev C. Cortical steady-state responses to central and peripheral auditory beats. Cerebral Cortex 2008;18:1193-200.
2. Wahbeh H, Calabrese C, Zwickey H. Binaural beat technology in humans: A pilot study to assess psychologic and physiologic effects. J Altern Complement Med 2007;13:25-32.
3. Lane JD, Kasian SJ, Owens JE, Marsh GR. Binaural auditory beats affect vigilance performance and mood. Physiol Behav 1998;63:249-52.
4. Lavallee CF, Koren SA, Persinger MA. A quantitative electroencephalographic study of meditation and binaural beat entrainment. J Altern Complement Med 2011;17:351-5.
5. Padmanabhan R, Hildreth AJ, Laws D. A prospective, randomized, controlled study examining binaural beat audio and pre-operative anxiety in patients undergoing general anaesthesia for day case surgery. Anaesthesia 2005;60:874-7.
6. Reedijk SA, Bolders A, Hommel B. The impact of binaural beats on creativity. Front Hum Neurosci 2013;7:786.
7. Takahashi T, Murata T, Hamada T, Omori M, Kosaka H, Kikuchi M, *et al*. Changes in EEG and autonomic nervous activity during meditation and their association with personality traits. Int J Psychophysiol 2005;55:199-207.
8. Lagopoulos J, Xu J, Rasmussen I, Vik A, Malhi GS, Eliassen CF, *et al*. Increased theta and alpha EEG activity during nondirective meditation. J Altern Complement Med 2009;15:1187-92.
9. Jirakittayakorn N, Wongsawat Y. Brain responses to a 6-Hz binaural beat: Effects on general theta rhythm and frontal midline theta activity. Front Neurosci 2017;11:365.
10. Raglin JS, Morgan WP. Influence of exercise and quiet rest on state anxiety and blood pressure. Med Sci Sports Exerc 1987;19:456-63.
11. Boutcher SH, Landers DM. The effects of vigorous exercise on anxiety heart rate and alpha activity of runners and nonrunners. Psychophysiology 1988;25:696-702.
12. Kubitz K, Pothakos K. Does aerobic exercise decrease brain activation? J Sport Exerc Psychol 1997;19:291-301.
13. Swain DP, Abernathy KS, Smith CS, Lee SJ, Bunn SA. Target heart rates for the development of cardiorespiratory fitness. Med Sci Sports Exerc 1994;26:112-6.
14. Qiu S, Cai X, Sun Z, Li L, Zuegel M, Steinacker JM, *et al*. Heart rate recovery and risk of cardiovascular events and all-cause mortality: A meta-analysis of prospective cohort studies. J Am Heart Assoc 2017;6:e005505.
15. Sydo N, Sydo T, Carta KA, Hussain N, Farooq S, Murphy JG, *et al*. Prognostic performance of heart rate recovery on an

exercise test in a primary prevention population. J Am Heart Assoc 2018;7:e008143.
16. Goldberger JJ, Le FK, Lahiri M, Kannankeril PJ, Ng J, Kadish AH. Assessment of parasympathetic reactivation after exercise. Am J Physiol Heart Circ Physiol 2006;290:H2446-52.
17. Tulppo MP, Kiviniemi AM, Hautala AJ, Kallio M, Seppänen T, Tiinanen S, *et al*. Sympatho-vagal interaction in the recovery phase of exercise. Clin Physiol Funct Imaging 2011;31:272-81.
18. Imai K, Sato H, Hori M, Kusuoka H, Ozaki H, Yokoyama H, *et al*. Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure. J Am Coll Cardiol 1994;24:1529-35.
19. Salmon P. Effects of physical exercise on anxiety, depression and sensitivity to stress: A unifying theory. Clin Psychol Rev 2001;21:33-61.
20. Santaella DF, Araújo EA, Ortega KC, Tinucci T, Mion D Jr., Negrão CE, *et al*. After effects of exercise and relaxation on blood pressure. Clin J Sport Med 2006;16:341-7.

How to cite this article: Pandey M, Saluja AK, Shrivastava R, Sinha M. Effect of 6 Hz theta frequency binaural beats on post-exercise heart rate and blood pressure recovery. Natl J Physiol Pharm Pharmacol 2023;13(07):1415-1420.

Source of Support: Nil, **Conflicts of Interest:** None declared.