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## Effects of Binaural Auditory Beats on Eye-hand Coordination in Young Population

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### KEYWORDS

Alternative wall toss test  
Beta binaural beat  
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Eye-hand coordination

### DECLARATIONS

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### ABSTRACT

**Background:** Binaural auditory therapy is one of the emerging fields of neuroscience with potential health benefits for the human brain. Many ranges of brain waves can be enhanced by the use of external auditory stimulus, which in turn augments brain activity. **Objective:** To determine the effects of beta binaural beats on eye-hand coordination in the young population. **Methodology:** This cross-sectional comparative study was conducted over 12 months from January 2023 to January 2024 at the Foundation University College of Physical Therapy, Islamabad, consisted of 66 healthy individuals aged 19-44 years of both genders, while exclusion criteria included conditions affecting sensory or cognitive function, physical limitations, regular cricket players, and other health issues that could hinder task performance. Data collection was initiated after obtaining approval from the Institutional Research Committee and Ethical Review Committee of Foundation University. Data was gathered using a self-structured questionnaire to screen participants and collect demographic details. Body mass index was calculated using weight and height measurements. The primary assessment tool was the Alternate Wall Toss test, where participants stood two meters from a wall and alternately threw and caught a tennis ball between hands for 30 seconds, with the number of successful catches recorded for eye-hand coordination scoring. The descriptive statistics, including means, frequencies, and percentages, were calculated to summarize participant characteristics. The Mann-Whitney U test was applied to compare medians, interquartile ranges, and assess statistical significance between groups. **Results:** In this study, there is a significant effect of beta binaural beats on eye-hand coordination in the young population, as the p-value was less than 0.05. By applying the Mann-Whitney U-Test, the Median of the level of coordination was 5.0, and its p-value was 0.02, so the results are significant and there is a positive effect of beta binaural beat on eye-hand coordination in the young population. **Conclusion:** It was concluded from the study that beta binaural beats have significant effects on eye-hand coordination of the young population. There exists a positive relation between the level of coordination and the male gender; males have an overall higher level of coordination than females.

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## INTRODUCTION

Our brain produces many waves of different frequencies in different states of the brain for proper cortical functioning. But what happens if the brain is not able to produce such waves adequately? This usually happens in various neurological disorders such as ADHD (Attention Deficit/Hyperactivity Disorder) and Parkinson's disease. It is such an interesting area of research to find out different ways to improve brain waves and their effects. The Binaural beats stimulation is one of the ways to improve brain waves by synchronizing the frequency of external stimulation with the frequency of brain waves. Binaural beat phenomenon is a kind of brainwave entrainment that occurs when two carrier tones of slightly different frequency and constant amplitude are given to the right and left ear, respectively, at the same time, and as a result, a new tone of single frequency is perceived by the brain. This illusory tone is equal to the difference of two carrier frequencies.<sup>1</sup>

According to previous research, the frequency limit of illusory tone is between 2Hz and 35Hz to carry out the binaural beat phenomenon.<sup>2</sup> Research has shown that the carrier tones should be between 400Hz and 500Hz to cause this phenomenon.<sup>3</sup> Moreover, pure tones are generally less than 1500Hz.<sup>4</sup> Cortical studies theorized that the electrocortical activity recorded with the help of an Electroencephalograph (EEG), as a brainwave's oscillation, consists of a wide range of frequencies. The most interesting point to consider is that every band of frequency is associated with a particular behavior and cognition. Enhancement of neuronal activity occurs when brainwave frequency synchronizes with the frequency of external auditory stimulus, which in turn powers various cognitive functions.<sup>5</sup> This phenomenon begins at the level of the superior olivary nucleus and the brainstem.<sup>6,7</sup> and then proceeds to the reticular formation<sup>8</sup> and the cerebral cortex.<sup>4,6</sup> This shows that every external sound is processed by the brain differently and has different effects on brain functions.

One study proved that swimming exercises can improve eye-hand coordination significantly.<sup>9</sup> Another research explained the importance of eye-hand coordination by proving that table tennis athletes with trained eye-hand coordination performed better in the sport than the untrained ones.<sup>10</sup> Researchers proved that there is a

significant positive effect of brain exercises on eye-hand coordination.<sup>11</sup> In this study, we investigated the effect of brainwaves on eye-hand coordination in addition to brain exercises to improve the coordinated feature of hand and eye movements. Our research revolves around the uses of binaural auditory beats and their potential health benefits, but it needs more literature. Thus, we have tried to investigate the effect of a beta acoustic beat with a resultant frequency of 25Hz and carrier frequencies of 385Hz in the left ear and 410Hz  $\beta$ -acoustic frequency in the corresponding right ear. At the same time, the difference in magnitude of these two signals will provide a certain perceived wave frequency. And to compare the results of eye-hand coordination for beta auditory beats and white noise.

## METHODOLOGY

This cross-sectional comparative study was conducted over 12 months from January 2023 to January 2024 at the Foundation University College of Physical Therapy (FUCP), Islamabad. The study utilized a consecutive sampling technique to recruit 66 participants, determined using the OpenEpi tool. Inclusion criteria consisted of healthy individuals aged 19-44 years of both genders, while exclusion criteria included conditions affecting sensory or cognitive function, physical limitations, regular cricket players, and other health issues that could hinder task performance. Data collection was initiated after obtaining approval from the Institutional Research Committee and Ethical Review Committee of Foundation University. Informed consent was taken from all participants before beginning the procedure.

Data was gathered using a self-structured questionnaire to screen participants and collect demographic details. Body mass index (BMI) was calculated using weight and height measurements. The primary assessment tool was the Alternate Wall Toss Test, where participants stood two meters from a wall and alternately threw and caught a tennis ball between hands for 30 seconds, with the number of successful catches recorded for eye-hand coordination scoring. SPSS version 21 was used for data analysis, and the descriptive statistics, including means, medians, frequencies, and percentages, were calculated to summarize participant characteristics and test results. The Mann-Whitney U test was applied to compare medians, interquartile ranges, and assess

statistical significance between groups. Ethical standards were upheld throughout the research by maintaining participant confidentiality and ensuring voluntary participation.

## RESULTS

Data were initially collected from 65 individuals. However, 13 participants were excluded for not meeting the study's inclusion criteria, resulting in a final sample size of 52 individuals. The demographic details of the participants are summarized in Table 1 below. Of the total sample, 26 participants (50%) were female and 26 (50%) were male. While the study targeted a younger population, the actual age range of the participants was between 19 and 44 years, and the mean age was  $23.96 \pm 4.80$ . The most frequently occurring age was 23 years, represented by 12 participants. The BMI classifications were based on World Health Organization (WHO) criteria. Upon analyzing BMI scores, it was found that 13 participants (25%) were underweight. The majority, 31 participants (59.6%), had a normal BMI, while 6 individuals (11.5%) were classified as overweight, and 2 participants (3.8%) were categorized as obese. The majority of participants were students, accounting for 40 individuals (76.9%). Other occupational categories included 5 teachers (9.6%), 4 staff members (7.7%), 2 house officers (3.8%), and 1 librarian (1.9%).

To evaluate the normality of the data, the Shapiro-Wilk Test was employed, and the data are mentioned in Table 2. The results indicated a p-value of less than 0.05, suggesting that the data were not normally distributed. Consequently, a non-parametric test, the Mann-Whitney U-Test, was applied to assess levels of coordination across three trials and their average, under both beta wave and white noise conditions. The test revealed no significant differences in Trial 1 ( $p=0.21$ ) and Trial 2 ( $p=0.11$ ). However, Trial 3 showed a statistically significant difference with a p-value less than 0.05. The median (IQR) level of coordination was 5.0, with a p-value of 0.05. Table 3 shows further results. In the beta wave group, 6 out of 26 participants (23%) demonstrated an average level of coordination.

Fair and poor coordination levels were observed equally in 10 participants each (38.5%). In contrast, the white noise group showed lower performance: only 2 out of 26 participants (7.7%) exhibited average coordination, while 6 (23.1%)

had fair coordination, and a majority of 18 participants (69.2%) demonstrated poor coordination. Gender-based analysis revealed differences in coordination levels. Among male participants, 8 out of 26 (30.8%) achieved average coordination, whereas none of the female participants reached this level. Fair coordination was observed in 12 males (46.2%) compared to 4 females (15.4%). Poor coordination was more prevalent among females, with 22 out of 26 (84.6%) displaying poor coordination, while only 6 males (23.1%) fell into this category.

The relationship between occupation and coordination levels is detailed further. Among the 40 students, 6 participants (15%) exhibited average coordination, 13 (32.5%) demonstrated fair coordination, and 21 (52.5%) had poor coordination. Within the teacher group, 3 out of 5 participants (60%) showed fair coordination, while the remaining 2 (40%) had poor coordination; none demonstrated average coordination. Among staff, 1 participant (25%)

**Table 1: Descriptive statistics of participants**

Variables		Frequency (f)	Percentage (%)
Age (years)	19	6	11.5
	20	6	11.5
	21	2	3.8
	22	8	15.4
	23	12	23.1
	24	5	9.6
	25	2	3.8
	26	2	3.8
	28	1	1.9
	29	1	1.9
	31	2	3.8
	32	2	3.8
	33	1	1.9
	39	1	1.9
	41	1	1.9
BMI	Underweight	13	25
	Normal	31	59.6
	Overweight	6	11.5
	Obese	2	3.8
Occupation	House Officers	2	3.80%
	Librarian	1	1.90%
	Staff	4	7.70%
	Student	40	76.90%
	Teacher	5	9.60%

**Table 2: Mann-Whitney U-test**

Variables	Median (IQR)		p-value
	Group A	Group B	
Trial 1	15 (9.50)	12 (7.25)	0.21
Trial 2	16 (9)	12.5 (7.75)	0.11
Trial 3	16 (8.50)	11.5 (8.25)	0.04
Average	16 (9)	11 (7.25)	0.08
Level of Coordination	4 (1)	5 (1)	0.05

**Table 3: Level of coordination**

		Average	Fair	Poor
Group	Beta waves	6 (23.1)	10 (38.5)	10 (38.5)
	White noise	2 (7.7)	6 (23.1)	18 (69.2)
Gender	Male	8 (30.8)	12 (46.2)	6 (23.1)
	Female	0	4 (15.4)	22 (84.6)
Occupation	House officer	0	0	2 (100)
	Librarian	1 (100)	0	0
	Staff	1 (25)	0	3 (75.)
	Student	6 (15)	13 (32.5)	21 (52.5)
	Teacher	0	3 (60)	2 (40)

exhibited average coordination, and 3 (75%) had poor coordination. Both house officers (n=2) exhibited poor coordination. The librarian, being the sole participant in that category, demonstrated average coordination (Table 3).

In summary, the data suggest a variation in coordination levels across different conditions, genders, and occupational groups. Beta wave stimulation appears to be associated with better coordination outcomes compared to white noise. Additionally, males outperformed females in terms of coordination, and students, being the largest subgroup, showed a wide distribution across coordination levels, although the majority still demonstrated poor coordination. This distribution pattern was even more pronounced in other occupation categories with smaller sample sizes.

## DISCUSSION

In 2023, Sandhya Basu and Bidisha Banerjee conducted a meta-analysis and systemically reviewed the potential of binaural beats for improving attention and memory, which may enhance the learning and focus of the listener. Our

research, on the other hand, revolves around the efficacy of binaural beats in their potential to either improve or worsen the eye-hand coordination mechanism in the young and middle-aged population.<sup>12</sup>

In 2020, A pilot study was conducted in which they developed an equipment that uses binaural beats to improve neural control and eye-hand coordination in healthy subjects. We used an online standard tool as a source of generating binaural beats, which has also been used in several other studies.<sup>13</sup> In 1980, Robert F. Hink and K. Kadera conducted a study that depicted the binaural interaction of a beating frequency-following response, which may indicate the synchronization of brainstem activity with auditory stimuli. This research work comprises a standard wall-toss test and its respective trial methodologies, which undergo the supervision of beta-binaural beat signals.<sup>6</sup>

Haas M, Sequeira Boeschen AM exploring the effectiveness of therapeutic listening 'Quickshift', a sound-based intervention that used binaural beat technology on bilateral coordination in healthy



adults with frequencies of low alpha and beta range lying between 8 and 13 Hz and the results were rendered rather insignificant but we used a particular 25Hz of frequency of beta-wave and the results obtained had more significant findings.<sup>14</sup>

In 2020, Bokil conducted a study involving athletes from various sports like archery, shooting, and fencing. The purpose of this study was to evaluate the degree of improvement in reaction time after toss training for 5 weeks. It was discovered that the treatment group had significant improvement in reaction time compared to the control group, and male athletes have better reaction time than female athletes. The alternate hand wall toss activity is used as an exercise by the experimental group to improve reaction time, which is measured by the ruler drop test. This activity is used in the form of a test to measure levels of coordination in response to either beta wave or white noise stimulation. Since reaction time plays an important role in coordinated movement, the results of our research are in line with this study, as males have better levels of coordination compared to females.<sup>15</sup>

Jeneviv N John studied the relationship between BMI and waist-to-hip ratio of 29 professional soccer players based on their playing order, ranging from forward, midfielder, defender, and goalkeeper, with eye-hand coordination by using the alternate hand wall toss test.<sup>16</sup> Pearson's product-moment correlation and linear regression were utilized to assess the reliability of the wall toss test, which is  $r=0.84$ . A statistically significant negative correlation with  $p=0.03$  was found between waist-to-hip ratio and coordination only in midfielders; however, no significant relationship was found between coordination and BMI in any of the 4 positions.

In our research, we only looked at the relationship of BMI with the level of coordination with the two largest groups of underweight BMI (less than 18.5) and normal BMI (18.5 - 24.9). In the underweight BMI group, the percentages of participants, 8%, 38%, and 54% represent average, fair, and poor levels of coordination, respectively. In the normal BMI group, the percentages of participants 13%, 26%, 61% represent average, fair, and poor levels of coordination, respectively. Since there are not enough participants in the overweight and obese categories, it is difficult to establish a relationship of coordination with BMI, making our results in line with this research.

Future studies could compare the effects of different types of binaural beats, such as alpha, gamma, or theta, on coordination and see if there is a correlation between the level of coordination and the frequency of the beat. Investigation can be made on the individual differences in responses due to the influence of binaural beats, i.e., whether factors like the levels of dopamine manipulate the outcome of the intervention. Further exploration of the binaural beats on coordination by measuring the performance of participants in tasks requiring basic motor skills like balancing, catching, and throwing. The optimal timing and duration of binaural beat exposure for improving coordination, and whether there are any diminishing returns or adverse effects of overuse, can be determined by later research.

## CONCLUSION

The results of this study suggest that there is no significant difference in trial 1 and trial 2 of both binaural beta beats and white noise. But there is a significant difference in trial 3. There also exists a positive relation between the level of coordination and the male gender, and males have an overall higher level of coordination than females. Since 77% of males, which is a large majority, are above a poor level of coordination, whereas 85% of females are at poor levels of coordination.

## DECLARATIONS

**Consent to participate:** Written consent had been obtained from patients. All methods were performed following the relevant guidelines and regulations.

**Availability of Data and Materials:** Data will be made available upon request. The corresponding author will submit all dataset files.

**Competing interests:** None

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**Authors' contributions:** All authors had read and approved the final manuscript.

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