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THE EFFECT OF ACOUSTIC EXPOSURE ON THE FREQUENCY-DEPENDENT SENSITIVITY OF THE AUDITORY SYSTEM

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Abstract: *This study comprehensively investigates the effect of acoustic exposure on the frequency-dependent sensitivity of the human auditory system. In particular, the fundamental physical properties of sound—frequency, amplitude, intensity, and wavelength—as well as the mechanisms by which these parameters are perceived by the auditory system, were analyzed. Based on experimental measurements conducted among students, the impact of headphone use on hearing acuity was evaluated. The results indicate that prolonged exposure to high-intensity sound, especially at high frequencies, leads to a decrease in auditory sensitivity. This issue is particularly relevant as it is widely observed among modern youth.*

Keywords: *acoustic exposure, auditory system, frequency, amplitude, sound intensity, audiometry, binaural beats, hearing acuity, headphones, dB, Hz*

INTRODUCTION

Sound is a set of mechanical vibrations that propagate through an elastic medium and are perceived by humans via the auditory system. The human auditory analyzer has a complex structure consisting of the outer, middle, and inner ear. One of its key features is selective sensitivity to frequency. Typically, the human ear can perceive sound waves in the range of 20 Hz to 20 kHz. However, sensitivity is not uniform across all frequencies: the mid-frequency range (approximately 2–5 kHz) demonstrates the highest sensitivity.

Acoustic exposure refers to the sound energy affecting the ear over a certain period of time. The intensity (dB), duration, and frequency composition of this exposure significantly influence the functional state of the auditory system. In modern lifestyles, especially among young people, the widespread use of headphones has increased acoustic load, making it an important risk factor for hearing health.

The main objective of this study is to determine the effects of sound parameters on the auditory system and to experimentally evaluate the impact of headphone use on hearing acuity.

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Literature review. The auditory system and acoustic exposure have been widely studied in scientific research. Modern sources highlight the following key conclusions: the human auditory system is most sensitive to sounds in the 2–5 kHz range, prolonged exposure to sounds above 85 dB can lead to sensorineural hearing loss, a characteristic hearing loss pattern known as the “noise-induced hearing loss notch” is typically observed around 4000 Hz.

Improper and prolonged use of headphones has been identified as one of the main causes of hearing impairment among young people. Additionally, the phenomenon of binaural beats has been studied, referring to a subjective auditory effect resulting from the brain’s integration of two different frequencies. While some studies report effects on cognitive states, its therapeutic effectiveness has not yet been fully scientifically validated.

Methodology. This study was conducted among students of a medical institute, with a total of 29 participants. The main evaluated parameters included: Type of headphones (over-ear, in-ear, AirPods), daily duration of use (hours), volume level (%), duration of headphone use (years)

Hearing sensitivity was measured at frequencies of 1000 Hz, 4000 Hz, and 8000 Hz, with each ear assessed separately (Table 1). Measurements were performed using a specialized mobile application, “Frequency Sound Generator.” The testing conditions were standardized as follows: Use of the same technical device, consistent sound level, quiet environment free from external noise.

Right Ear

ID	Ear	Time (hours)	Height %	Duration (years)	1000 Hz	4000 Hz	8000 Hz	Headphones
1	R	3,5	45	2	19	17	27	over
2	R	1,5	20	1	20	22	16	over
3	R	3	30	1	17	26	21	air pods
4	R	1	40	1	17	19	30	air pods
5	R	1,5	45	1	20	16	18	air pods
6	R	3,5	50	3	17	29	22	in
7	R	0	0	0	18	21	16	0
8	R	1	10	1	17	26	36	air pods
9	R	2 3	45	2	16	17	23	over
10	R	2	45	1	25	21	30	air pods
11	R	1	50	1	19	20	23	over
12	R	2	75	3	19	18	24	over
13	R	2,5	30	1	20	34	50	air pods
14	R	1	10	1	18	29	25	in
15	R	c	30	1	16	17	19	air pods

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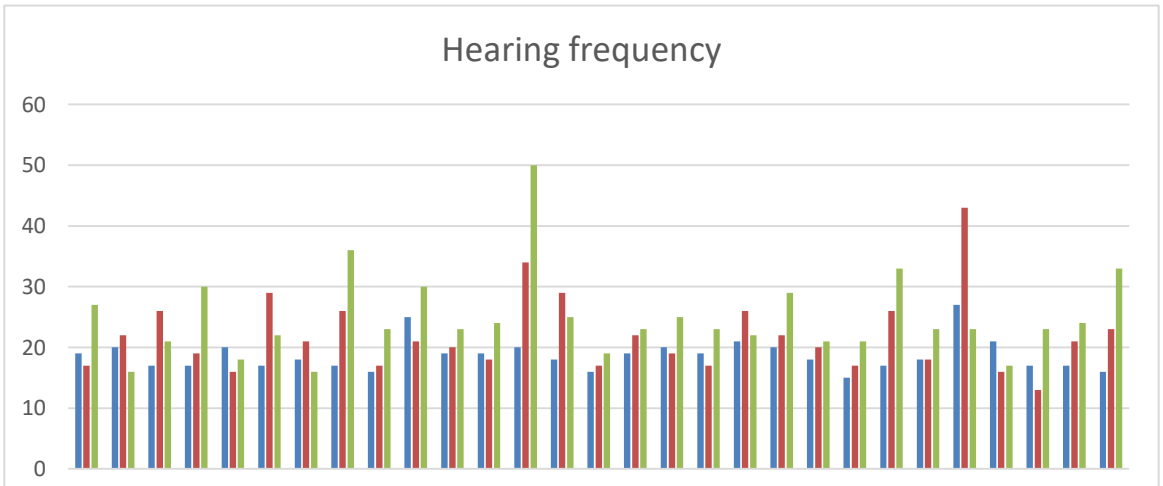
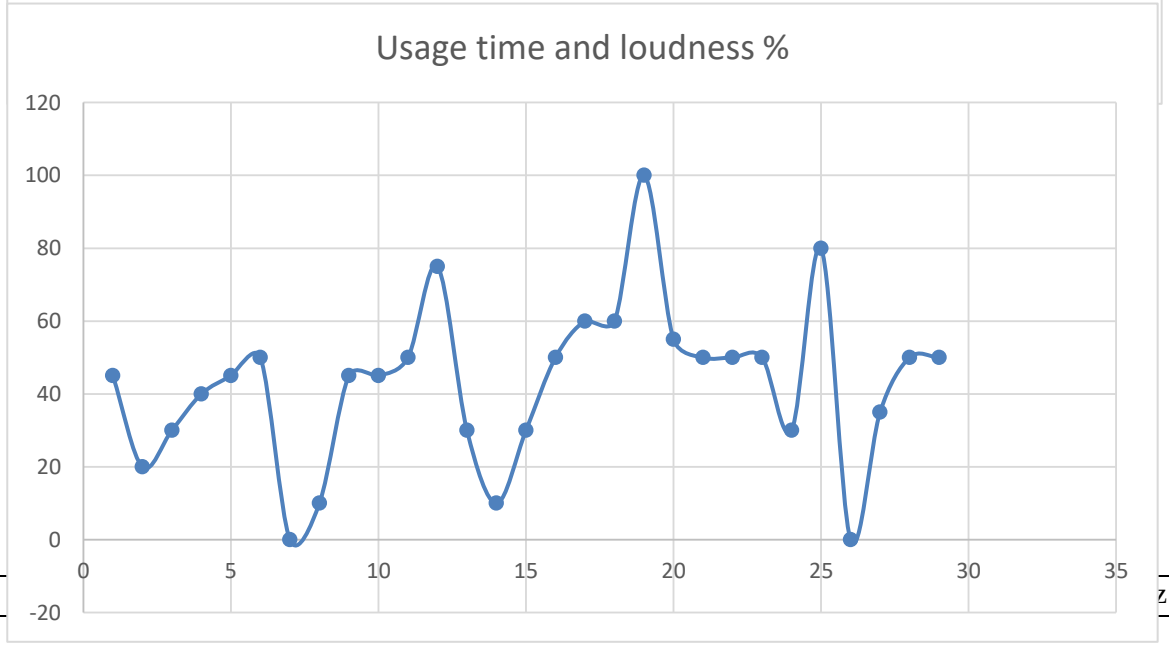
16	R	3	50	1	19	22	23	air pods
17	R	2	60	2	20	19	25	air pods
18	R	2	60	2	19	17	23	air pods
19	R	3,5	100	1	21	26	22	air pods
20	R	0,5	55	1	20	22	29	over
21	R	2	50	1	18	20	21	in
22	R	1	50	1	15	17	21	in
23	R	1	50	0,5	17	26	33	in
24	R	1	30	0,5	18	18	23	in
25	R	2	80	1	27	43	23	air pods
26	R	0	0	0	21	16	17	0
27	R	2	35	0,5	17	13	23	air pods
28	R	1	50	1	17	21	24	air pods
29	R	1	50	2	16	23	33	air pods





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		(hours)					
1	L	3,5	45	2	17	20	22
2	L	1,5	20	1	17	20	18
3	L	3	30	1	15	24	20
4	L	1	40	1	19	18	17
5	L	1,5	45	1	18	19	17
6	L	3,5	50	3	17	33	21
7	L	0	0	0	17	17	17
8	L	1	10	1	16	26	35
9	L	2,5	55	2	18	17	20
10	L	2	55	1	22	23	28
11	L	1	50	1	24	19	26
12	L	2	55	3	18	21	24
13	L	2,5	30	1	20	21	32
14	L	1	10	1	16	32	26
15	L	4	30	1	15	21	17
16	L	3	50	1	19	30	40
17	L	2	60	2	22	19	24
18	L	2	60	2	20	20	21
19	L	3,5	100	1	20	18	26
20	L	0,5	55	1	19	24	21
21	L	2	50	1	17	23	20
22	L	1	50	1	14	19	25
23	L	1	50	0,5	18	28	32
24	L	1	30	0,5	15	17	19
25	L	2	80	1	15	20	18
26	L	0	0	0	21	16	17
27	L	2	35	0,5	14	20	21
28	L	1	50	1	17	26	24
29	L	1	50	2	19	23	49

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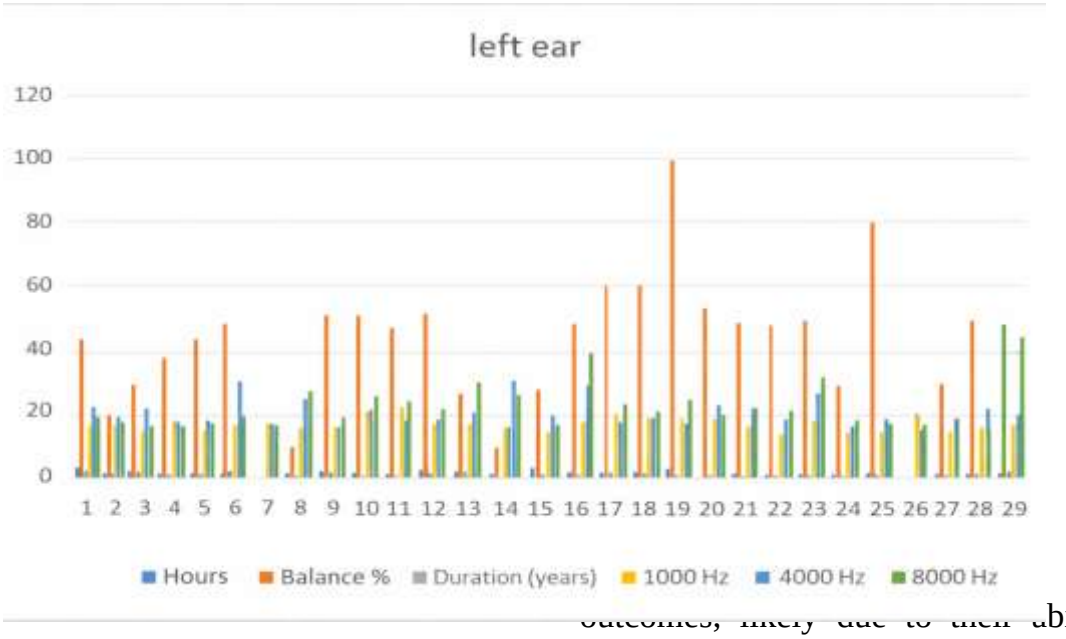

Analysis and results. The study results revealed significant variations in the frequency-dependent sensitivity of the auditory system.

General hearing status: Most participants had hearing thresholds within 15–25 dB, which is considered physiologically normal. However, in some participants, particularly in the 4000–8000 Hz range, a decline to 30–50 dB was observed, indicating early signs of hearing impairment.

Frequency-dependent sensitivity: The greatest decline was recorded at high frequencies (4000–8000 Hz). This suggests that hair cells in the inner ear are particularly sensitive and vulnerable to damage in this range.

Effect of headphone type: Users of in-ear and AirPods-type headphones showed greater deterioration in high-frequency hearing. Over-ear headphones demonstrated relatively safer outcomes, likely due to their ability to isolate external noise.

Time factor: 0–1 hour of use: normal hearing indicators, 2–4 hours: onset of noticeable decline, More than 3–4 hours of regular use: poorest results

Sound intensity (volume level): Up to 50%: relatively safe, 60–80%: risk zone, 80–100%: harmful to the auditory system

Individual differences: Significant differences between the right and left ears were observed in some participants. In many cases, the right ear exhibited poorer hearing, possibly associated with the habit of using a single earbud.

Conclusion and recommendations. The findings demonstrate that acoustic exposure directly affects the frequency-dependent sensitivity of the auditory system. In particular, hearing loss at high frequencies is closely associated with acoustic load. Improper use of

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headphones emerges as a major contributing factor to hearing impairment. Therefore, strengthening preventive measures is of great importance.

Practical recommendations: Follow the 60/60 rule: do not exceed 60% volume and limit continuous use to 60 minutes. Prefer over-ear headphones. Take a 10–15 minute break every hour. Undergo audiometric testing at least once a year. Increase awareness among students and young people about hearing hygiene. If you want, I can also refine this into a journal-ready (Scopus-style) version with more formal phrasing and formatting.

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