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Original Research

The Effects of Binaural Audio On Static and Dynamic Balance

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Abstract

Objectives: This study aimed to examine the effects of virtual binaural audio on static and dynamic balance in healthy young adults.
Materials and Methods: Forty-eight healthy individuals between the ages of 18 and 65 participated in this study. Data were collected using a descriptive information form, the Berg Balance Scale, the Flamingo Balance Test, and the Y Balance Test (YBT). Both the Flamingo Balance Test and YBT were applied to all participants in the absence and presence of binaural audio.
Results: The Flamingo Balance Test results of the participants in the presence of sound were found to be significantly better than those in the absence of sound. Their YBT results were also significantly improved in the presence of sound.
Conclusion: The results of this study indicate that binaural audio may change the static and dynamic balance in healthy young adults.

Keywords: *static balance, dynamic balance, binaural audio, postural sway, sound localization*.

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Introduction

Balance refers to the maintenance of the center of gravity over the base of support during rest and movement to prevent falling and is achieved as a result of postural sway and adjustment (Palmieri et al., 2002). There are two types of balance, namely static and dynamic balance. Static balance refers to the ability to keep the body in a fixed position, and dynamic balance refers to the ability to maintain the balanced position of the body during movement and ensure the continuation of this balance throughout the entire movement (Mahafza et al., 2022).

In humans, posture is controlled by the central nervous system interpreting multi-sensory inputs. The visual, somatosensory, and vestibular systems are involved in maintaining balance (Maurer et al., 2006). Visual information plays an important role in maintaining balance (Kelly et al., 2008). Good visual fixation helps increase balance stabilization, but activity increases body sway and deteriorates balance stabilization (Mergner et al., 2005). Auditory information has a role in providing balance as much as visual information. The environmental sound increases postural control and reduces postural sway with the auditory feedback mechanism. Sound is important for postural sway and motor control because sound perception is not limited to advanced spatial information as in the visual system. Regardless of its direction, the stimulus contributes to the regulation of postural sway (Gandemer et al., 2014). In daily life, auditory information works in harmony with other sensory processes. Auditory functions become more effective and necessary in maintaining balance in visually impaired individuals. This situation is slightly different in individuals with hearing loss. Although the visual system compensates for the auditory system, sound perception contributes significantly to postural control (Kanegaonkar et al., 2012). In addition to visual cues, the correct localization of sounds in our environment allows us to have information about the environment. Sounds and noises we hear in our daily lives are multi-sensory and active. Binaural audio or environmental audio refers to the technology of realistically adjusting the arrival directions of sounds. In the context of binaural audio, sound is created by making use of the interaural time and intensity differences of sounds coming from speakers placed at many different angles. The higher the number of types of sound and the number of speakers, the closer to reality the sound becomes (Gaveau et al., 2022; Kogan et al., 2018). In cognitive theories, the interaction of the individual with their environment is directly proportional to the effectiveness of the response created by the system (Seifert et al., 2020). Binaural sound involves the simultaneous detection of different sounds in the environment by imitating the human ear. The purpose of binaural sound is to try to provide a realistic sense of localization (Morton, 2004).

There are several studies on the effects of noise on hearing and balance functions, suggesting that the brain elicits better responses in cases of multiple sensory stimuli (Stevens et al., 2016). Therefore, this study aimed to examine the effects of virtual binaural audio on balance in healthy young adults.

Materials and Methods

Our study was approved by the ethics committee of Ondokuz Mayıs University (2022-461). A power analysis was performed using the G*Power software (G*Power Ver. 3.0.10, Universitat Düsseldorf, Düsseldorf Germany). As a result, the sample size required for the study was found to be 48, considering 95% power and a 5% margin of error. Our study included individuals between the ages of 18 and 65 who had no health issues that could affect their balance, obtained Berg Balance Scale scores between 41 and 56 and had normal hearing. All experiments were carried out in accordance with the Declaration of Helsinki, and all participants provided informed consent.

Data were collected using a descriptive information form, the Berg Balance Scale, the Flamingo Balance Test, which is used to evaluate static balance performance, and the Y Balance Test, which is used to evaluate dynamic balance performance.

The Flamingo Balance Test is a valid and reliable test to evaluate static balance (Tsigilis et al., 2002). It consists of a 50 cm long, 4 cm high, and 3 cm wide wooden block and requires the participant to stand on one leg on a beam, with the other leg flexed at the knee and the foot of this leg held close to the buttocks. The total number of falls or losses of balance in one minute of balancing without support is counted. During this period, whenever the balance is disturbed, the stopwatch is stopped, and the participant is expected to take the same position again. The test is restarted each time the balance is disturbed. After one minute, the test is terminated (Çinar-Medeni et al., 2015; Sember et al., 2020).

The Y Balance Test (YBT) is a valid and reliable test to evaluate dynamic postural control quickly and easily. YBT is a dynamic test performed while the participant stands on one foot without support while lying barefoot in three directions (anterior, A; posteromedial, PM, and posterolateral, PL) (Plisky et al., 2009). After the participant stands on the foot plate in the middle of the test area, they extend the other foot to the farthest possible point on the line in the direction shown (A-PM-PL) without losing the one-leg stance and completing the test by returning to the starting point. During the test, three attempts are made for each leg in three

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directions (A-PM-PL), and the maximum distance achieved is recorded in cm (Linek et al., 2017; Robinson & Gribble, 2008; Wilson et al., 2018).

Both the Flamingo Balance Test and YBT were performed by all participants in our study in the absence and presence of sound using binaural audio using JBL T4660BT supra-aural wireless headphones (Harman International Industries, USA) at a volume that would not disturb the individual. The binaural sound recording that was used consisted of real sounds from different environments using multiple microphones. The audio recording that was used was produced by people on YouTube (Ambience, 2021)

Statistical Analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) v22.0. Descriptive statistics are given as mean and standard deviation values. Parametric tests were used to analyze the Flamingo Balance Test and YBT results of the participants, and a one-sample t-test was used to compare the measurements made at different times. The level of statistical significance was accepted as $p<0.05$.

Results

A total of 48 healthy individuals with normal hearing and no balance issues were included in our study. The mean age of the participants was 29.39±9.27 years (range: 18-50 years). Among the participants, 26 (54.2%) were female with a mean age of 28.42±8.67 years, and 22 (45.8%) were male, with a mean age of 30.54±10.01 years. Additionally, 41 (85.4%) of the participants had their dominant extremity on the right side, and 7 (14.6%) had their dominant extremity on their left side. The mean Berg Balance Scale score of the participants was 56, and 83.7% of the participants did not have regular physical activity habits.

The Flamingo Balance Test results of the participants in the presence of sound were found to be significantly better than their results in the absence of sound ($p<0.05$). Their YBT results were also significantly improved in the presence of sound compared to their results in the absence of sound ($p<0.05$) (Table 1).

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Tablo 1. Flamingo and YBT balance test results

	Absense sound	Presense sound	P value
Flamingo Balance Test	4.47±3.77	1.97±2.14	0.000*
Y Balance Test (right extremity)	88.91±20.10	93.81±16.20	0.001*
Y Balance Test (left extremity)	90.68±16.03	94.00±16.55	0.000*

* $p<0.05$

Discussion and Conclusion

Balance disorders are an important health issue worldwide and increase the risk of falling by aging (Stewart et al., 2020). Balance is associated with multi-sensory information flow from the visual, vestibular, somatosensory, and auditory pathways. A disorder in any of these systems affects our balance system (Ross et al., 2016). Although vestibular information is the main element, and visual information is the complementary element in providing balance, auditory information also plays an important role in this regard. Binaural hearing refers to the spatial localization of the visual system with interaural time and intensity differences, as well as frequency selectivity (Zhong & Yost, 2013). Our study examined the effects of environmental sounds on balance and revealed that environmental sounds reduced postural sway and improved static and dynamic balance scores.

Literature has examined the effects of stimuli on static and dynamic balance using different stimuli introduced to the sensory system or motor system (Severini & Delahunt, 2018; Zhong & Yost, 2013). Severini et al. applied white Gaussian noise to the tibialis anterior muscle at different intensities and durations and reported that the stimulus increased the sensitivity of receptors, reduced postural sway and positively affected balance (Severini & Delahunt, 2018). Zhong and Yost examined the effects of broadband noise from a fixed sound source on balance in healthy individuals and found that the auditory cue significantly increased postural stability. They also reported that while visual information provided a 98% benefit in achieving balance, auditory information provided a 76% benefit and reduced postural sway (Zhong & Yost, 2013). Ross et al. investigated the effects of white noise on postural oscillation in different age groups and reported that white noise reduced postural sway and raised balance stability despite age-related sensory impairments (Ross et al., 2016). Sound plays an effective role in the achievement of postural control. A study evaluated the effects of sound on the balance system in different static auditory environments and showed that the sound helped maintain postural

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stability, and the amount of auditory information provided about the environment was directly proportional to the decrease in oscillation and the increase in balance. As a result, the richer the auditory environment is, the more individuals use the "spatial hearing map" theory to interpret their environment and increase their balance stabilization capacity (Gandemer et al., 2017).

Auditory cues from the surrounding environment have positive effects on maintaining balance. However, this situation varies according to the intensity of ambient noise and the duration of exposure to sound. Selcuk et al. examined the effects of sound on vestibular functions and balance among professional musicians and found that long-term exposure to sound affected balance functions negatively (Selçuk et al., 2021). As a consequence of exposure to noise, not only does hearing loss occur, but apoptosis is observed in hair cells in the vestibular system, increasing postural sway and causing balance disorders (Themann & Masterson, 2019). As a result of the decrease in multi-sensory inputs in age-related hearing loss, the perception of auditory cues also decreases and affects balance negatively. Thus, balance disorders and falls occur at older ages (Davis et al., 2016). Regarding the hearing and balance system, Wolter et al. studied the effects of voice on the balance system in children with cochlear implants and found that the earlier the children were implanted and the sooner they recognized environmental sounds, the better their balance stabilization became (Wolter et al., 2021).

There is a significant relationship between sound and the balance system. In the literature, there are several studies on the effects of sound on balance, using different auditory information or stimuli, but there is no study involving binaural audio in this regard (Brown, 2010; Kogan et al., 2018) It is known that the amount of environmental auditory information is directly proportional to the degree of balance stabilization. In light of this information, we used binaural audio obtained using an artificial ear from different environments in our study (Kogan et al., 2018). As a result, we determined an improvement in static and dynamic balance scores in the presence of binaural audio. We consider that binaural audio can be used in exercise programs to reduce postural sway in balance disorders in therapeutic treatment and rehabilitation processes. There is a need for further studies on this subject using different vestibular diseases and age groups. Our study has some limitations, such as not using the assessment of balance with golden standards like posturography.

In conclusion, the intensity of environmental sound information contributes positively to the balance system. We consider that performing exercises using binaural audio stimuli in balance rehabilitation programs will have a curative effect on rehabilitation outcomes.

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Declaration of Competing Interest

The authors have no conflicts of interest to declare.

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