THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DIVISION OF SCIENCE

The Effects of Auditory Input on Balance in Healthy College-Aged Students

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Spring 2023

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Kinesiology
with honors in Kinesiology

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ABSTRACT

Balance ability is required for people to stay upright. In humans, balance ability can be determined through postural stability, the ability to control various movements and maintain body posture. Someone with a higher balance ability is at a decreased likelihood for falling. Balance ability can be measured using standardized tools such as the Berg Balance Scale, Wobbleboards, and Force Plates. Force Plates are a more accurate and precise way to measure stability. The purpose of this study was to determine how various auditory noises can affect postural stability. The hypothesis was that moving auditory noise playing unequally between headphones will be more destabilizing than when static noise that plays equally between headphones. Data on postural stability with no noise, static noise, and moving noise was collected using a force plate. Data was calculated and analyzed using SPSS software. Statistical significance was then calculated using a one-way repeated measures analysis of variance (ANOVA). Among all participants, there were no statistically significant effects found when looking at 5 measures of instability including total distance moved, center of pressure (COP) velocity, movement in the Anterior Posterior (AP) directions, movement in the Medial Lateral (ML) directions, and area COP. However, when looking specifically at individuals who perceived an 8D audio as rotating around their head in a circle, a significant difference was found in area COP. This research suggests that auditory input has no overall effect on balance when looking at a population of college students. The research also suggests that how an individual perceives audio can have a significant impact on the direction of postural leaning and may influence an individual to replicate the rotating pattern found in music such as 8D audio.

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ACKNOWLEDGEMENTS

I would first like to thank my thesis advisor, Dr. Benjamin Infantolino, for guiding me throughout my academic journey and encouraging me to become a Penn State Schreyer scholar. Your guidance is what helped me decide on Occupational Therapy as my future career path.

I would also like to thank my honors advisor, Dr. Sandy Feinstein, for assisting me throughout my academic journey. Your support encouraged me to keep pushing myself and to strive for success.

Thank you, Brandon, for always being there for me and supporting me every step of the way. Your love and encouragement help me to push myself and succeed during the most challenging times.

Finally, thank you Mom and Dad for everything that you do for me. I truly appreciate the guidance, encouragement and support you have always given me. I could not have done it without you.

Chapter 1: Introduction

1.1 General Introduction

Maintaining a balanced upright posture is essential for everyday life, and falling has the capacity to produce life altering effects such as injury resulting in financial burden. For young populations, problems that may arise from falling include injuries such as a scratch on the skin, a broken arm or other injuries that are an inconvenience to that individual but likely not fatal. In aging populations, however, falling is more likely to produce severe injuries such as a broken hip or head injury that can lead to the death of that individual. With a rapidly increasing elderly population, research on balance and fall prevention is even more essential now than ever.

Various methods have been used to examine an individual's postural stability in order to predict a likelihood of falling. The Berg Balance Scale (BBS) is a field assessment tool used to determine an individual’s stability and to predict fall risk during everyday movements (Berg, 1992). The BBS test is a cheap method to measure balance ability. The effectiveness of the test in predicting falls, however, has shown mixed results. (e.g., Lajoie and Gallagher, 2004; Chiu et al., 2003; O’Brien et al., 1998; Boulgarides et al., 2003). Attempts have been made to establish a score threshold to indicate a high likelihood of a potential fall. Some researchers suggested the threshold score be set at 45 on the BBS (Scott et al., 2007) while other research on the same topic has determined that 54 is the optimal cutoff for increased fall risk (Muir et al., 2008). Uncertainty of optimal cutoff numbers makes the BBS difficult to use for research on postural stability.

An improved method of measuring postural stability involves the use of a force plate, which is an expensive piece of equipment that allows researchers to precisely measure ground reaction forces and moments produced during human movement. Using force plates, ground reaction forces can be measured in the X, Y, and Z directions in addition to movement around those axes. The movement in the XYZ coordinates can then be used in relation to the human body which is tracked as movement in the anterior, posterior, medial, and lateral directions.

Most of the recent research on postural stability has examined how changes in the visual field throw off a person's stability. Visual aspects of research include situations such as eyes open vs eyes closed, low-vision vs normal-vision, and eyes fixed vs eyes moving (Melzer et al., 2004; Tomomitsu et al., 2013; Williams et al., 2017). When presented with eyes closed conditions during research, a destabilizing effect was demonstrated among elderly and college-aged subjects (Melzer et al., 2004; Reed et al., 2020). Research on the effects of visual stimulation on postural stability has been proven and studied by many different researchers (Lord and Menz, 2000; Reed-Jones et al., 2008; Horlings et al. 2009; Laurens et al., 2010; Tsutsumi et al., 2010; Raffi et al., 2014).

One area of research that has been less studied is the effect of auditory input on postural stability. With advances in technology, music and other auditory input, noises are constantly around us. When people wear headphones they have the capability to play music directly into their ears and block outside auditory stimulation. Headphones have become so common that they are being worn while exercising, operating heavy machinery, or even walking from one location to another. It is critical that balance is maintained during these tasks for the safety of those performing them or others surrounding them. When using more than one speaker, as headphones do, it is possible to have audio play from one speaker but not the other. Using multiple speakers has the possibility to create an effect that feels like the music is traveling from one location to another. If auditory stimulation becomes out of sync with the environment surrounding headphone users, it may produce destabilizing effects that can lead to an increased number of preventable falls.

Research on the effects of auditory stimulation on postural stability is a relatively new area of research that has been growing within the past few years. Research on balance and auditory stimulation has shown significant effects (Yashima et al., 2021; Gandemer et al., 2014; Xingyu and Xingda, 2017). However, most research focused on using white noise stimulation rather than typical music people listen to every day (Gandemer et al., 2014; Yashima et al., 2021).

1.2 Purpose of Study

The purpose of this study is to determine the effects of auditory input on postural stability. Falls are not only the cause of many injuries in all populations but are also a leading cause of death in elderly populations. This study will allow us to determine if there are certain auditory noises that populations at risk of falling, such as elderly individuals, should avoid or ones that may help increase stability. Avoiding destabilizing noises would work as a fall prevention measure for individuals who are more susceptible to falling.

1.3 Specific Aims

The specific aims were

1. To measure initial postural stability of participants with no auditory stimulation

2. To measure postural stability during stereo-panning audio situations

3. To measure postural stability during stable audio situations

4. To compare stability during auditory stimulation with initial stability

1.4 Study Overview

Measuring and understanding postural stability is important to recognize an individual's likelihood of falling. Force plates make it possible to track and calculate movement of the human body during static stance. The more movement that is produced, the more unbalanced someone is, which increases their likelihood of falling. External stimulation such as auditory noise has the ability to produce destabilizing effects. Some music has been created to produce an effect that feels like it is moving or rotating side to side when wearing headphones or using more than one speaker. If this noise is out of sync with the environment around the user, it may produce a leaning effect towards the sound.

1.5 Thesis Structure

Chapter two reviews relevant literature. Chapter three outlines the methods used in this study. Chapter four reveals the results of this study. Chapter five contains the discussion and conclusion to this study.

Chapter 2: Literature Review

2.1 Overview

This chapter reviews literature on various methods of measuring postural stability.

Section 2.2 provides an overview of some of the original literature that helped define postural stability, section 2.2.1 discusses common measurements used to establish instability, section 2.2.2 takes a deeper look into the use of force plates, the measurement tool this research uses to measure postural stability. Section 2.3 defines the differences between center of pressure data and center of mass. Section 2.3.1 evaluates Anterior-Posterior and Medial-Lateral measurements while section 2.3.2 evaluates the uses of an Ellipse area in research to evaluate stability. Section 2.4 describes the use of transient behavior in postural control. Section 2.5 examines previous research on the effects of auditory input on static balance. Section 2.6 summarizes this chapter and clarifies what measurement tool will be used and why.

2.2 Postural Stability

The body's ability to balance or stay upright without falling is due to postural stability, the ability to control movement of the body to maintain an upright posture. Research on this topic first appeared in 1906 and, again, in 1915 by C.S. Sherrington (1906, 1915) who stated that “posture follows movement like a shadow,” meaning that the interaction between movement and posture is very closely related. Further research on this topic has been conducted by additional scientists: Magnus (1924) was one of the original investigators on vestibular function; Rademaker (1931) researched static balance responses in animals without a cerebellum; and Winter et al., (2003) examined motor differences of the hip and ankle muscles during quiet standing. Further research on this topic continues and attempts to determine what variables can aid in increasing postural stability. Research on postural stability is necessary to confirm the proposed negative effects the environment can have on an individual's ability to stay upright without falling. Stability measures provide us with information on an individual's likelihood to fall and possibly allow us to prevent future falls.

2.2.1 Measures of Stability

Various methods have been used to measure postural stability. The Berg Balance Scale (BBS) is a series of short tests run to determine static balance ability and assess fall risk in aging populations. The list of short tests includes sitting on a chair to standing with no use of support and standing to sitting with no use of support; standing with eyes closed; transfer from one chair to another in a pivoting motion; standing with feet together; reaching arm straight out in front while standing; picking an object up off the ground while standing; looking over shoulder while standing; turning a full 360-degrees; placing one foot on a step stool while standing unsupported; and standing on one leg unsupported. The Berg Balance Scale consists of 14 tasks as listed above scored from 0-4, 0 meaning the test subjects were unable to perform the task and 4 meaning the task was performed independently without the use of arm rests or assistance from the assessor. The highest possible score for the BBS is 56, which would indicate there are no identifiable balance difficulties. A lower score on these tests would indicate a lower level of stability and an increased likelihood for falls (Berg, 1992).

Research by Muir et al. (2008) investigated the validity of the BBS in predicting multiple falls in elderly populations. Their study analyzed 210 community-dwelling older adults with a mean age of 79.47 years ranging from 47-90 years old. They also used field data from “The Project to

Prevent Falls in Veterans" with men making up 65% of the participants. Of the 210 analyzed, only 187 of the participants had complete data sets at the end of the one-year follow-up period due to dropouts. They investigated three potential outcomes in their research: those who sustain a fall, multiple falls, and injurious falls. The collected data were then evaluated on 5 factors: sensitivity, specificity, receiver operating characteristic (ROC) curves, area under the curve, and likelihood ratios. First, they mailed out a cross sectional screening survey to identify potential modifiable risk factors in research participants. Modifiable risk factors include the use of four or more prescription medications, lower-extremity muscle weakness, stability problems, foot problems, and any reported vision problems. Those who reported no modifiable risk factors were assigned to the control group. Those who reported 1-5 modifiable risk factors were randomly assigned to either a regional geriatric care program or community based primary care. From here, a comprehensive geriatric assessment was performed to acquire baseline data. Participants were given a "fall calendar" and asked to mark how many times they fell and what type of fall occurred. A fall was considered a period of unintentional rest on the floor or ground while an injurious fall required a visit to a physician. Researchers calculated the sensitivities and specificities of BBS scores for each of the fall outcomes and plotted them on an ROC curve. Their research found that only when using ROC analysis does the BBS have good discriminative ability to predict multiple falls. Previous research had set a fall risk value on the BBS at 45, but their findings using ROC analysis showed the optimal cutoff was 53 or 54 for people who had fallen multiple times and had any type of fall including an injurious fall. This finding meant that a significant number of people scoring above the previously set score of 45 on the BBS were experiencing falls. The first major limitation to this study was that they acquired their data from part of an intervention study. Participants in this study had been previously exposed to information on fall prevention which, if followed and were successful, may have caused an underestimation in the predictive validity of the BBS for elderly populations. Another limitation to the study was that injurious falls were self-reported and not confirmed with a participant's medical records, which may have resulted in under reporting in the injurious falls category. A third limitation to this study was a potential lack of generalizability due to several factors including: the data being pulled from a study on fall prevention, a majority of the participants being men and military veterans, and potential lack of follow-up data in healthier individuals.

Other ways to measure stability use equipment such as a wobble board. The wobble board can be used in individuals with better balance. It is made up of a board that allows for either 360-degree motion or motion within a given plane. For research purposes it is connected to a measurement device such as a potentiometer that records movement throughout the plane.

Research by Williams et al. (2017) investigated the reliability and variability of the SMARTwobble using standard error of the mean (SEM) and minimum detectable changes (MDC). The SMARTwobble is a wireless wobble board, with tilt sensors that relay movement information to computer software to be plotted and interpreted. Their research used 32 healthy college-aged students, mean age of 23, with no known musculoskeletal or neurological disorders that may affect balance. Participants were instructed to stand on the board with their feet along the outer edge and attempt to maintain a level board. They were then instructed to perform five tasks on the board: double leg stance; double leg stance with eyes fixed on a central point; double leg stance with eyes roaming around a grid comprised of scattered numbers in order to find the numbers in numerical order; double leg stance with eyes closed; single leg stance with eyes fixed; and a single leg stance with eyes roaming around the grid with scattered numbers as mentioned previously. Each task was performed three times for one minute in a randomized order with a minimum of 90 seconds of rest in between tasks. Their findings showed good reliability and low variability when using the board and collecting data on the same day. They found a standard error mean of 4% and minimal detectable change of 9%, which allow for differentiation between board performance and participant interaction with the board. A major limitation of this research is that participants were allowed a three-minute familiarization period with the board and the five tasks, which could have led to a learning effect in their results, meaning the participants results could have improved during the three-minute period. Another limitation is that participants were healthy college-aged students with no disorders affecting balance. Lastly, some of the college-aged students may have had prior experience using the SMARTwobble which could limit the generalizability of their results for populations with no prior experience on the board.

2.2.2 Force Plates

Force Plates are some of the most widely used tools in assessing postural stability in laboratory settings. They are used to detect ground reaction forces and various movements within the human body such as acceleration, and they provide data points that allow us to measure postural stability.

Research by Melzer et al. (2004) measured postural stability and attempted to identify various risk factors for falls in an elderly population. Their research included 143 subjects aged 65 or older. Nineteen of those subjects had reported having at least two unexpected falls in the last six months and were placed into the fall group. Researchers instructed participants to fold their hands behind their back and stand as still as possible on a force plate. Two primary factors were measured: narrow and wide stance over a series of three tests, each lasting 20 seconds. The three tests consisted of eyes open, eyes closed/blindfolded, and eyes open standing on foam. Center of pressure (COP) data from the force plate was sampled at a frequency of 100Hz. An analysis of variance (ANOVA) test was performed to determine mean differences between the two groups in the six testing conditions. Data collection and analysis included COP path length; COP velocities; elliptical area; medio-lateral (ML) sway; and antero-posterior (AP) sway. They found that there were no significant differences in the postural stability of fallers vs non-fallers when using a wide stance. There were, however, significant differences in postural stability of fallers vs non-fallers when using a narrow stance. They found that fallers had a significantly higher COP velocity, COP path length, and ML sway when being compared to non-fallers. When testing the standing on foam condition, they found that fallers when compared to non-fallers had a significantly higher ML sway and a higher elliptical area. During the eyes closed measurements, fallers had significantly higher COP velocity, COP path length, elliptical area, and ML sway. In general, their analysis showed that participants with a higher medio-lateral sway were three times more at risk for falling. Some limitations to this study include learning effect and generalizability. A learning effect may be present in the data because participants were instructed to practice several times before the actual test was administered. The generalizability of the results may be affected by the fact the research used a very small sample size (19) for their group of fallers.

Schubert et al. (2020) used force plates to determine differences in postural stability among various populations and situations. Research by Schubert et al. (2020) examined differences in postural stability in musicians when compared to non-musicians. Three hundred ninety college students participated in this study; 345 of which were music students with a mean age of 23.4 ± 4.5 years and 44 were nonmusicians aged 23.1 ± 2.9 years who made up the control group. The musicians were further divided into groups based on their primary instrument. The seven instrumental categories included: “upper” strings; “lower” strings; woodwinds; brass; flutes; bassoons; and “others” (harp and accordion). Their research used the Zebris FDM-S force plate to record static posturography of the participants. The two main factors they collected data for were postural balance and a sway in center of pressure, measured by movement in ground reaction force, to observe the subject's oscillation patterns during static stance. Participants were instructed to stand on the force plate without shoes in a relaxed stance. Data were recorded for 20 seconds for each trial and averaged for the recording period. Two conditions were measured: standing in a neutral position with hands at their sides and standing with arms stretched out directly in front of the body to form a 90-degree angle with the torso and held for the 20 second recording period. Using their postural sway data, an ellipse of confidence, an oval surrounding most of the data points to measure COP displacement, was created to include 95% of the data collected. High values for this data would indicate an elevated level of postural sway and high instability while low values would indicate the opposite results. Their results found that many musicians had significant instrument specific and potentially harmful postural differences when compared to the control group. For example, musicians such as pianists and guitar players showed a weight distribution shifted more to the left when compared to the control group. However, lower string players and percussionists showed a weight distribution shifted more to the right when compared to the control group. These results may indicate a decrease in balance due to the postural distributions of each subject putting more weight or pressure towards one side of their body rather than the pressure being centered and evenly distributed between both feet. One limitation to this study was the small sample size per instrument group once musicians were divided. Low sample size per instrument could further limit the generalizability of the results per instrument. Another is that many students play more than one instrument, which may show a postural bias when only taking their primary instrument into consideration.

2.3 COP/COM

The most common way to assess changes in postural control is with changes in the center of pressure (COP) data using a force plate. A force plate allows us to pinpoint the bodies vertical ground reaction force and creates data points over a set amount of time. Using COP data allows researchers to determine the area of postural sway, mean velocity, and path length. COP data is what will be used in this research to identify potential instabilities in an individual's balance. Often confused with COP measures, changes in the center of mass (COM) take into consideration the changes in density throughout an object. In humans, the COM is found around the belly button in normal stance but will change with limb movement. Data for these factors can be examined on a statokinesigram used only in the horizontal plane.

2.3.1 AP/ML velocity

Using a force plate allows for the calculation of anterior posterior (AP) and medial lateral (ML) velocities. Movement in each direction will show an increase in velocity and, therefore, a decrease in postural stability. Points in the AP/ML directions are compiled into a stabilogram, showing movement in each direction over time. Research by Prieto et al (1996) examined various measures of postural steadiness and changes in steadiness with age. Their research used 20 young adults with a mean age of 26.4 years and 20 elderly adults with a mean age of 68. Force plate amplifiers provided data points for AP and ML time series. The collected data were then filtered through a low-pass digital filter set to cut-off at a 5-Hz frequency. Their results indicated a larger postural sway in the AP direction when compared to the mean COP. A significant difference was found between the young adult and elderly population in the AP data.

2.3.2 Ellipse area/surface

The ellipse area covers 90-95% of the COP data points in the anterior posterior and medial lateral directions. Data points in each of the 4 directions can be used to calculate overall postural performance. The more spread out the data points are around the ellipse can be associated with worse overall performance in maintaining balance. Research by Prieto et al. (1996) examined various measures of postural steadiness in healthy young adults and elderly adults using a force plate. One of the COP based measurements used in their research was the 95% confidence ellipse area. Their data showed a mean difference in postural stability between young and elderly adults when using a 95% confidence ellipse area. The reason ellipse area and other COP measurements are used in research is because they are relatively easy to obtain and have been proven effective in determining fall risk. Their data collection was set at a sampling frequency for their amplifiers at 100 Hz for 30 seconds. The collected data then allowed them to calculate the area within a sway path using the area of a 95% confidence ellipse.

2.4 Transient Behavior of Postural Control

Research by Reed et al. (2020) examined transient response in center of pressure data when paired with a sensory transition such as participants closing their eyes. Their study contained three experiments to collect and measure data of various responses in different populations. Their study excluded individuals with known neurological impairment, previous joint replacement surgery for the lower extremities or a lower extremity injury that occurred within the past three months prior to testing. For their first experiment, participants included 67 young adults aged 24.9 ± 3.9 years. In this experiment, they examined what additional information could be found when comparing whole-trial estimates of data to specific transient characteristics of postural control. The second experiment had 30 young adults aged 22.9 ± 2.6 years who had participated in the first experiment but agreed to additional testing for the second experiment. In this experiment, researchers examined postural control difference in eyes open versus eyes closed situations. The third experiment used all 67 young adults from the first experiment and 38 older adults that were able to stand for more than five minutes without any form of aid. In this experiment, researchers examined the differences in postural control in older adults compared to younger adults. Previous research typically examined COP data for periods of 1-2 minutes. This research attempted to identify data using a short initial period (~15s) of destabilization immediately following a sensory transition such as closing your eyes. All participants were instructed to stand as still as possible on a force plate with no shoes and the medial borders of their feet spaced 5cm apart. Participants were instructed to count down aloud starting at three and then say go, which indicated they would immediately close their eyes and start the trial. Three successful quiet eyes closed (QEC) trials were then performed for 60 seconds with adequate rest time in between as determined by each individual participant. The 60 second COP data were then divided into twelve 5 –second epochs. The 1st and 12th epoch's data were compared to get an idea of data points from beginning to end. Then the 1st and 3rd epoch's data were compared for transient postural behavior before a quasi-steady state was achieved. Their results found that using the 'Epoch' fixed effect there were significant differences in experiment two for quiet eyes closed (QEC) and quiet eyes open conditions. They also found significant differences in postural control when comparing the younger and older adult groups using this approach. One major limitation to their research was that errors in experiment 1 may be carried over to experiment 2 and 3 since they used the same data collected in experiment 1 to calculate postural instabilities for each participant. Potential error when reusing data may cause miscalculations when examining the statistical significance of their findings.

2.5 Auditory Stimulation and Postural Stability

Based on research done by Gandemer et al. (2014) and Yashima et al. (2021), there appears to be a correlation between auditory stimulation and postural stability. Research by Gandemer et al. (2014) investigated how horizontally rotating white noise affects postural stability. For their research, they used 20 young subjects, 12 males (25.2±3.9 years) and 8 females (24.9±3.3 years) who were physically active and had no history of vestibular, visual, or auditory disease. Their research was conducted in a soundproof room with a 360-degree audio system comprised of 16 loudspeakers. Participants were instructed to stand on a force plate barefoot with feet together. The experiment was conducted in a dark room with the participant wearing a blindfold to ensure results were not affected by visual stimuli. Data were collected over a 70 second period, 50 seconds of rotating sound immediately followed by 20 seconds of stationary sound coming from a speaker placed directly in front of the participants. The data collection was divided into 3 rounds of 4 trials which presented 4 different white noise stimuli; a 3-minute rest period occurred between each of the three rounds. COP data were then calculated from the force plate using the area of the sway path and amplitude of sway. The researchers found that postural stability showed an initial decrease in the first 10 seconds of the trial followed by a steady state. Velocity showed a sudden increase at the 50 second mark when the sound stopped rotating and remained stationary in front of the subjects. Their results showed that sway significantly decreased during the presence of rotating sound when compared to trials of stationary sound or no sound. One limitation to this research is the small sample size, which can affect the generalizability of their results. Another limitation could be difficulty in getting the speaker height at exactly ear level for each participant.

The research by Yashima et al. (2021) examined the effects of stationary white noise on static balance in healthy young adults. Eighteen young college students, 13 male and 5 female with a mean age of 26.2 ± 8.9 years participated in the study. Researchers instructed participants to attempt to balance on top of a Wii Fit balance board on the toes of one foot chosen by participants, with their eyes closed. They used a stopwatch to time how long the participants were able to balance on one foot to determine initial balance ability up to 60 seconds in which the trial ended. Measurements were taken 10 times with a period of 5-15 seconds rest in between each trial. The participant's initial balance ability results were then used to divide them into two experimental groups, one for individuals with a lower balance ability (less than 10 seconds) and one for individuals with a higher balance ability (10+ seconds). Each group then performed 20 trials standing on the Wii Fit board balancing on the toes of one foot with their eyes closed. However, during 10 of these trials, auditory white noise was administered binaurally via

Bluetooth headphones. Their results found that the lower balance group showed a significant increase in balance during the noise trials when compared with the no-noise trials. The high balance group showed no significant effects, which researchers stated was likely due to a ceiling effect meaning there was little to no room for improvement in balance ability due to the research parameters of a 60 second cap. Some limitations to this research include a learning effect and potential fatigue since subjects were performing 20 trials with minimal rest between each. Another limitation is the low sample size which may affect generalizability.

2.6 Summary

Various methods exist to measure postural stability in humans. Measurement resources such as the Berg Balance Scale, SMARTwobble, and Force Plates. Force Plates help with tracking and measuring instability, which may help predict and prevent falls from occurring in the future. The most efficient method for collecting and analyzing data is the use of force plates, which allow the tracking of movement in the AP and ML directions as well as forming an Ellipse area. All methods can be used to determine various amounts of instability in each direction of motion and assist with the tracking of changes when various modes of auditory input are introduced.

Chapter 3: Methods

3.1 Overview

This chapter provides an overview on the methods used to measure the amount of postural instability with the introduction of auditory noise. Section 3.2 describes the process used for participant selection. Section 3.3 discusses the types of auditory input that were selected. Section 3.3.1 describes what type of headphones were used to project the auditory input to participants. Section 3.3.2 discusses the order in which each trial occurred. Section 3.4 discusses the specific body positions followed by each participant during data collection to maintain consistency. Section 3.5 discusses force plate information and additional environmental factors that were controlled. Section 3.6 discusses the statistical analysis measures used to analyze the data. Section 3.7 summarizes the chapter.

3.2 Participant Selection

Participants were recruited for this study from within the student population at Penn State Berks. This was accomplished via fliers sent to multiple classes and word of mouth from fellow classmates. Participant selection was based on voluntary participation and based on student availability during data collection times. Since the current research intends to produce destabilizing effects on balance, using a college-aged population decreases the likelihood of falls during data collection.

3.3 Music Selection

Two versions of the same song were selected to be used in this research. The first version of the song that was selected played equally between two headphones the way we typically hear music; this version was established as non-moving or static audio in this research. The second version of the song that was selected played an edited 8D audio which produces a stereo panning effect that makes the music feel like it is moving or rotating around you; this version was deemed as the moving audio in this research. The moving/8D audio passes left and right from one headphone to the other at a frequency of approximately 2 seconds.

3.3.1 Headphones

The same pair of over the ear headphones were used during data collection to maintain consistency and ensure no changes occurred in sound projection, such as headphone quality or volume, between all trials. The headphones were wireless with Bluetooth capabilities to prevent potential movement of a subject caused by any motion coming from a headphone cord. The music was played at the same volume for each participant. Participants were asked to keep headphones on between each trial to make sure no buttons on the headphones were accidentally touched by the participant. Keeping the headphones on between trials also makes certain the headphones remained in the same spot throughout the data collection to keep the audio projection consistent among all 7 trials.

3.3.2 Music Order

The sequences of the audio trials were purposely selected, not randomized, to prevent trials of moving audio from playing before trials with static audio in order to decrease the likelihood of residual effects in decreased balance ability that may occur after moving auditory scenarios. Starting with a no noise trial, initial balance ability was established and used as a comparison for each participants balance ability during conditions using noise. Participants were given time between each trial to recover from potentially destabilizing effects before the next trial began.

3.4 Participant Instruction

Participants were instructed to stand on the force plate (Bertec, Colombus, OH) with their feet together with heels and toes touching, eyes closed, and hands on their hips. Having all participants stand with their feet together helped with maintaining consistency and slightly decreased postural stability among a population with typically good balance ability. Having participants close their eyes during data collection ensures that results are not produced from any visual field stimulation. Putting hands on hips ensures that participants did not move their hands and potentially throw off the data collected. The data collection occurred in a quiet room to prevent potential instability coming from noise not projected through the headphones. After 7 trials lasting 60 seconds each were completed, participants were asked how they perceived the 8D audio as moving within the headphones. This is because participants mainly perceived the 8D audio as traveling either left and right from one headphone to the other or in a circular motion around the head. Differences in audio perception may lead to different outcomes in how the body may replicate and move along in the same directions as the perceived music.

3.5 Force Plate

This research used a force plate and Bertec Acquire (Bertec, Colombus, OH) software for data collection. A sampling frequency of 1000 Hz was used during data collection. The force plate was zeroed between each trial. Each participant was instructed to stand towards the center of the force plate to ensure all data points were collected and consistency of body positioning was maintained between participants.

3.6. Statistical Analysis

Data analysis and calculations were performed using SPSS software. Calculations included postural the total distance moved, COP velocity of sway, movement in the Anterior/Posterior and Medial/Lateral directions, and the area COP. A one-way repeated measures ANOVA was used to produce calculations that determine the statistical significance for each of the five calculations listed above.

3.7 Summary

There were 7 trials of data collection with various noise and no noise conditions. Participants were instructed to stand on a force plate with their heels and toes completely touching together, hands on their hips, and eyes closed. The first trial was the no noise trial, which was used as a control to determine the subject's initial balance ability. The next 6 trials alternated between a nonmoving static sound played equally between two headphones and an 8D audio sound played unevenly between the headphones create an effect where the audio moves around the subject's head. Data collection was accomplished using a force plate and Bertec Acquire (Bertec, Colombus, OH) software. Data analysis and calculations were performed using SPSS software. Calculations for statistical significance were produced using a one-way repeated measures ANOVA.

Chapter 4: Results

4.1 Overview

This chapter provides the results of the study. Section 4.2 discusses the results of the study. Section 4.3 summarizes the chapter.

4.2 Results

In total, 40 college students attending Penn State Berks were analyzed for possible postural instability during various auditory conditions. Out of the 40 participants, 22 identified as males (55%) and 18 identified as female (45%). Data collection took place under 3 auditory conditions: no noise, static sound, and moving sound. The no noise condition was used as a baseline for each participant's initial balance ability. For the static and moving sound conditions, 3 trials of data collection were completed for each, and the results of the trials were averaged. Using a force plate, postural instability during each condition was measured five different ways: total distance moved, COP velocity, movement in the AP directions, movement in the ML directions, and area COP.

As a whole, no significant differences were found in the stability measures during any of the listed auditory conditions. Table 4.1 represents the values of significance found during analysis for each condition evaluated for postural stability.

Table 4.1 P-values to determine statistical significance. A p-value less than .05 denotes statistical significance.

Total Distance (cm)	p=.783
COP Velocity (cm/s)	p=.929
AP Excursion (cm)	p=.095
ML Excursion (cm)	p=.737
Area COP (cm^2)	p=.079

After data collection, participants reported how they perceived the moving audio. Table 4.2 represents the participants' perceptions of the moving audio stimulation.

Table 4.2 Participant perceptions of how the audio was moving during the moving sound conditions.

Moving in a circle (rotating around the head)	23
Moving left and right (passing from one headphone to the other)	7
Moving left and right then transforming into moving in a circle	6
Other (moving in a semicircle; moving forward and back)	4

No statistical significance was found (p=.232) when measuring movement in the ML directions for participants who reported hearing the audio as moving from left to right. Statistical significance (p=.009) was found in individuals who reported hearing the audio as moving in a circle when measuring the area COP.

4.3 Summary

The results of this study were presented in section 4.2 and table 4.1. The findings of this study conclude that auditory stimulation produces no significant effects on postural stability in college-aged students. Additionally, no significant results were found when looking at how each participant perceived the moving audio and the stability measure that analyzed movement in the same directions. However, significant results were found when examining how auditory stimulation perceived as moving in a circle affects postural stability measure as area COP.

Chapter 5: Discussion

5.1 Overview

The results of this study indicated that auditory input does not have a significant overall effect on balance in college-aged adults. Section 5.2 describes the significance of auditory research with regard to balance ability. Section 5.3 describes the limitations of this study in relation to the selection of subjects. Section 5.4 proposes recommendations for future research. Section 5.5 summarizes the research study.

5.2 Effects of Auditory Noise on Balance

The research hypothesis for this study was that selective auditory stimulation could produce a decreased balance ability that can lead to an increase in everyday falls. Preventing falls is important because falling can produce life altering effects such as head injuries, broken bones, or even death. The importance lies in determining what types of auditory input have a significant effect on either increasing or decreasing an individual's likelihood for falling.

Previous research on the topic of ways that auditory stimulation can influence balance ability has shown mixed results. Some research suggests that varying forms of auditory stimulation can produce destabilizing effects on balance in adults 18 and older (Xingyu and Xingda, 2017; Timofeeva et al., 2021). This current research study found no statistically significant difference in the overall effects that auditory stimulation had on balance ability in a college-aged population. Having results of no significance contradicts research by Xingyu and Xingda, 2017; Timofeeva et al., 2021, which both show that auditory noise produces a destabilizing effect on a subject's balance ability. Varying types of auditory sound projected to the subjects may account for differences in results. Another difference could be due to these earlier studies using participants older than college students used in the current study. In addition to the research studies that show destabilizing effects, some research studies suggest that auditory stimulation can produce stabilizing effects when it comes to balance (Yashima et al., 2021; Gandemer et al., 2014). The current research also contradicts the results found in studies done by Yashima et al., 2021; Gandemer et al., 2014. The results of this study found that there was no statistical significance in the overall effect of auditory stimulation on balance while these other research studies found auditory noise to have stabilizing effects on balance ability. The differences in results between this study and the others could be due to differences in the methods of projecting audio to the subjects (headphones vs. external speakers) or the speed in which the moving audio rotated around the subjects.

This study did, however, find a significant effect on the area COP in individuals that perceived the moving 8D audio as rotating in a circular motion around the head. This means auditory stimulation has the potential to produce a destabilizing effect specific to body sway moving in a way that replicates the sound as it is perceived. These results indicate that certain forms of auditory input have the potential to produce destabilizing effects depending on how the motion of a moving 8D audio is interpreted. Overall, no statistically significant difference was found in the overall effects that auditory stimulation has on balance ability in a college-aged population. The only significant effect found was on area COP when subjects perceived the 8D moving audio as rotating in a circle.

5.3 Limitations of Present Study

There were several limitations in this study design. The first is that subjects younger in age often have a better balance ability than older adults. Balance ability and the ability to compensate for instabilities in young populations may be so good that changes in the auditory environment are not enough to produce destabilizing effects. Another limitation to this study is that many individuals of younger generations are frequent headphone users. A review of multiple studies has shown that differences in how sound is projected to subjects whether by headphones versus external speakers may be an important factor (Lubetzky et al., 2020). The final limitation to this study could be that the 8D moving audio alternating back and forth between headphones at a frequency of 2 seconds does not give the human body enough time to change directions in postural sway.

5.4 Future Studies

Future studies should use a population older than college students that typically demonstrates a decreased overall balance ability. In addition, research using the college-aged population could use different methods that significantly decrease balance ability in any population, such as standing on one foot. It may also be beneficial for future studies to research how auditory input influences balance ability during a movement-based activity such as walking. One final suggestion for futures studies would be to add a question that asks subjects if they felt less stable during any of the auditory conditions and, if so, during which ones.

5.5 Conclusions

This study revealed that there was no statistically significant evidence that auditory input has an effect on balance ability. There is statistical evidence that shows how 8D or moving audios that are perceived as rotating around the head can potentially lead to postural leaning in a similar circular pattern. The methods used in this research can be extended to future research using subjects with a less stable balance ability. Though the effects of auditory input on balance ability are still widely unknown they may affect older adults more than younger adults.

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