Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Medicine and Health Sciences
Department of Neuromedicine and Movement Science

Rosa Kang

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Master's thesis in Physical Activity and Health
Supervisor: Ann-Katrin Stensdotter
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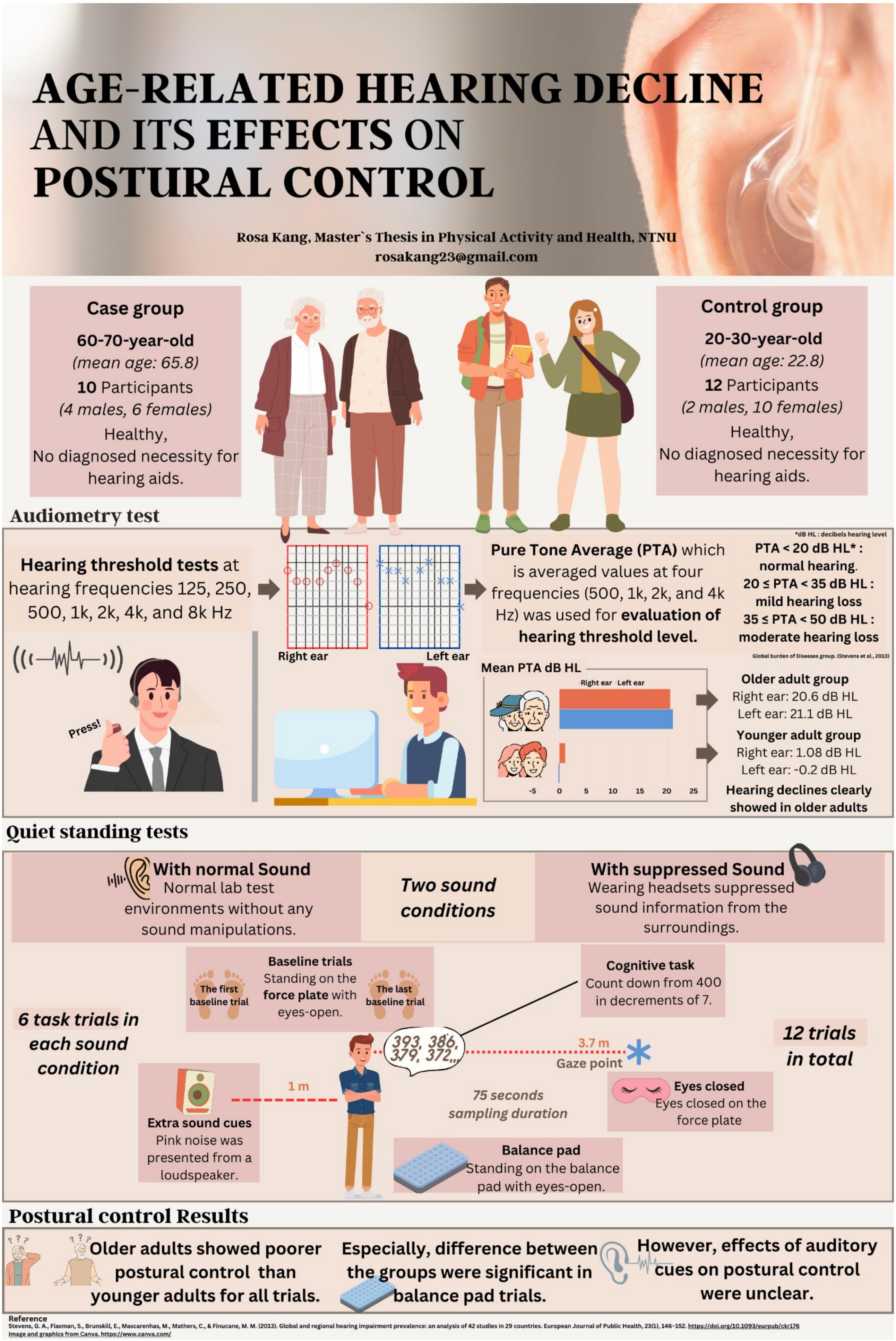
AGE-RELATED HEARING DECLINE AND ITS EFFECTS ON POSTURAL CONTROL
Rosa Kang, Master`s Thesis in Physical Activity and Health, NTNU
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Case group
60-70-year-old
(mean age: 65.8)
10 Participants
(4 males, 6 females)
Healthy,
No diagnosed necessity for hearing aids.
Control group
20-30-year-old
(mean age: 22.8)
12 Participants
(2 males, 10 females)
Healthy,
No diagnosed necessity for hearing aids.
Audiometry test
Hearing threshold tests at hearing frequencies 125, 250, 500, 1k, 2k, 4k, and 8k Hz
Right ear
Left ear
Pure Tone Average (PTA) which is averaged values at four frequencies (500, 1k, 2k, and 4k Hz) was used for evaluation of hearing threshold level.
*dB HL : decibels hearing level
PTA < 20 dB HL* : normal hearing.
20 ≤ PTA < 35 dB HL : mild hearing loss
35 ≤ PTA < 50 dB HL : moderate hearing loss
Global burden of Diseases group. (Stevens et al., 2013)
Press!
Mean PTA dB HL
Right ear
Left ear
-5
0
5
10
15
20
25
Older adult group
Right ear: 20.6 dB HL
Left ear: 21.1 dB HL
Younger adult group
Right ear: 1.08 dB HL
Left ear: -0.2 dB HL
Hearing declines clearly showed in older adults
Quiet standing tests
With normal Sound
Normal lab test environments without any sound manipulations.
Two sound conditions
With suppressed Sound
Wearing headsets suppressed sound information from the surroundings.
Baseline trials
Standing on the force plate with eyes-open.
The first baseline trial
The last baseline trial
Cognitive task
Count down from 400 in decrements of 7.
6 task trials in each sound condition
12 trials in total
393, 386, 379, 372,,
3.7 m
Gaze point
1 m
75 seconds sampling duration
Eyes closed
Eyes closed on the force plate
Extra sound cues
Pink noise was presented from a loudspeaker.
Balance pad
Standing on the balance pad with eyes-open.
Postural control Results
Older adults showed poorer postural control than younger adults for all trials.
Especially, difference between the groups were significant in balance pad trials.
However, effects of auditory cues on postural control were unclear.
Reference
Stevens, G. A., Flaxman, S., Brunskill, E., Mascarenhas, M., Mathers, C., & Finucane, M. M. (2013). Global and regional hearing impairment prevalence: an analysis of 42 studies in 29 countries. European Journal of Public Health, 23(1), 146–152. https://doi.org/10.1093/eurpub/ckr176
Image and graphics from Canva. https://www.canva.com/

Abstract

Background: The auditory system has been considered to have a contribution to postural control together with visual, somatosensory, and vestibular systems. Degradation of hearing acuity is prevalent in older populations, and it may affect high risk of falling due to the postural instability caused by hearing deficit. However, there has been no previous study focused on hearing decline in relation to particular age range.

Objective: The aim of the present study is to determine the impact of hearing decline with aging on postural control in older adults aged 60-70 years by comparison with younger adults aged 20-30 years.

Methods: 10 participants (4 males, 6 females, mean age: 65.8) in the case group and 12 participants (2 males, 10 females, mean age:22.8) in the control group were included. Two groups conducted an audiometry test and quiet standing tests. Pure tone average (PTA) was estimated for hearing thresholds. Sway velocity was measured for postural control evaluation. Six different test trials containing the first and the last baseline trials, eyes-closed, balance pad, provision of pink noise, and counting task trials were conducted with normal sound environment and suppressed sound environments where the participants wore headsets.

Results: PTA thresholds of two groups were significantly different. There were statistically significant inter-group differences with somatosensory modulation in total and anterior-posterior (AP) velocity results regardless of the sound conditions. Additionally, the provision of extra sound trial with normal sound environments and the first baseline trial with suppressed sound showed significant group differences in AP velocity. Medial-lateral (ML) velocity showed no difference between the groups. However, suppressed sound information with headsets and provision of pink noise did not have significant influence on sway velocity within each group.

Conclusion: Hearing acuity declines in company with postural control systems in 60-70-year-olds. However, the present study findings suggest that the effects of hearing decline on postural control in 60-70-year-olds showed ambiguity.

1. Introduction

The postural control system of the human body plays an important role in everyday life. It helps to maintain upright posture, perform a wide variety of movements and to recover stability by reacting against external forces (Pollock et al., 2000). Intricate interactions between the central nervous system, sensory and motor systems control the posture and retain balance. Once the central nervous system integrates sensory information provided by visual, somatosensory, and vestibular apparatus from the surroundings, the motor system generates or controls motions accordingly (Deliagina et al., 2006; Duarte & de Freitas, 2010).

Although hearing has not been considered as being part of the postural control system, it may be an important contributor to motor control. In addition to the three main sensory systems the auditory system uses spatial cues from sounds in the surroundings to aid the spatial orientation of the body (Gandemer et al., 2017). Auditory inputs provide information about the direction of the sound, with slight intervals between when the sound arrives at each ear (Interaural Time Differences, ITDs) and with a difference of the sound intensity (Interaural Level Differences, ILDs) (Hartmann, 1999). Additionally, processing of sound information helps with perceiving the distance to the location of sounds, as its amplification and frequency components change depending on the distance between the starting point of sound and the subject who is hearing (Campos et al., 2018). These auditory cues are utilized, together with other sensory inputs, to adapt and stabilize posture in accordance with the perception of the environment and self-motions within the environment. (Campos et al., 2018). In regard to the acoustic information, some researchers have proposed the theory that listeners construct the individual auditory maps based on their environment, which play a role as landmarks in a space to contribute to maintain the stable posture (Campos et al., 2018; Gandemer et al., 2017; Kanegaonkar et al., 2012).

Degradation of hearing has been revealed to have an association with an increased risk of falling caused by postural instability. Tests of pure-tone audiometry and self-reported questionnaires on incidents of falling have shown that even mild hearing loss can lead to a three-times higher likelihood of falling than normal hearing (Lin & Ferrucci, 2012). There are various causes of hearing loss, such as constant exposure to deleterious noise over a long period of time, ear infection and effusions, ototoxicity, genetic lesions and so on. Aging is also a key factor greatly affecting deterioration of hearing (Nadol, 1993). Indeed, the World Health Organization (WHO, 2023) reported the prevalence of hearing loss in people over the age of 60, and more than 25% of people were estimated to be living with disabling hearing impairment which corresponds to the degrees of hearing loss greater than 35 decibels (dB) hearing level (HL). Between the degrees of 20 dB HL and the 35 dB HL in the better hearing ear is considered as mild hearing impairment, and of more than 35 dB HL to 50 dB HL is considered moderate hearing loss in accordance with hearing impairment categories from Global Burden of Disease (GBD) (Stevens et al., 2013). A drastic increase in the elderly population and subsequent rising proportions of age-related hearing loss has become an issue of concern. Living with hearing loss often causes difficulties in daily life such as decreased participation in social-economic activity, increased risk of falling, reduced physical activity and risk of mortality induced from complex comorbidities regarding physical and mental health (Dalton et al., 2003; Davis et al., 2016; Solheim et al., 2011).

Age-related attenuation in hearing generally occurs simultaneously with declines of other sensory and motor systems. While an age-related decline of the main sensory functions - visual, somatosensory, and vestibular systems have been extensively studied in relation to poor balance and risk of falling during the past few decades, studies regarding the association between hearing and balance have only emerged and commenced in recent years. According to the previous research, it has been revealed that the absence of sound stimuli per se by either external or internal factors such as suppressed sound environments or hearing impairment is more likely to have an influence on postural instability rather than hearing deficits. Viljanen et al. (2009) reported that in 20 second standing tests with a semi-tandem stance, elderly females with poor hearing were shown to have larger sway velocity compared to those with normal hearing. Kanegaonkar et al. (2012) showed that during 30 seconds of quiet standing, the sway ellipse area collected from people with normal hearing increased in sound suppressed surroundings. In the research of Vitkovic et al. (2016), during quiet standing tests for 60 seconds, sway path length was measured, and moving extra sound inputs slightly reduced the path length of a normal hearing group in comparison with an ambient sound environment. Maheu et al. (2019) showed whilst there was no significant benefit of auditory information to sway area in a normal hearing group during 60 seconds standing tests, there was a benefit for those with hearing loss concurrent with a vestibular impaired group. Ninomiya et al. (2021) demonstrated that total sway area and mean sway velocity were improved with auditory inputs for both hearing aid users and normal hearing participants during quiet standing tests for 60 seconds. Although there is evidence from several studies supporting the fact that auditory systems contribute to maintain balance with auditory maps, more research is required for a more robust rationale, as some discrepancies between the studies, such as various sampling durations, sound environments, and feet positions may impede between-study consistency and research validity (Carpenter & Campos, 2020).

Furthermore, there has been no research which puts emphasis on the 60-70-year-old age range in relation to changes of hearing and its effect on postural instability. Age-related hearing loss is generally characterized by high-frequency hearing reduction. A previous study conducted in Wisconsin showed that an age group of 60-year-old participants exhibited hearing decline from the frequency range 4000 Hz and over in both genders, and the degeneration was proceeded to the low-frequency hearing range with the aging process (Cruickshanks et al., 1998). A relatively recent study also reported that greater than 30 % of the study population in aged 60-64 in both genders had mild hearing loss (> 20 dB HL), and for 65–69-year-olds the proportion of mild hearing loss increased to approximately 60 % and 45 % in male and female respectively (Homans et al., 2017). Nonetheless, prevalence of hearing loss in aging populations often tends to be overlooked and undetected by medical professionals as it has been considered to be part of the natural process of aging (Davis et al., 2016; Wallhagen & Pettengill, 2008). Thus, research on the decrease of hearing acuity and its association with postural control changes in this age group may provide meaningful implications to understand the mechanisms of the early stages of age-related attenuation in hearing and balance, as hearing decline is concomitant with the degeneration of other sensory systems attributed to advancing age.

This study mainly aimed to ascertain the effect of age-related hearing deterioration on postural stability during upright standing by comparing older adults aged 60–70 years to younger adults aged 20-30-years. In order to clarify the impact of the auditory cues on postural control with respect to other sensory modulations of visual and somatosensory information, diversified test conditions were used in this study.

2. Methods

Participants

Twenty-four persons volunteered and a total of 22 participants were included in this project. All satisfied the inclusion criteria which required them to be healthy without any diagnosed conditions that may impact postural control and no diagnosed need of hearing aids. The case group consisted of ten participants aged 60-70 years (4 males, 6 females) and 14 individuals aged 20-30 years (4 males, 10 females), were assigned to the control group. However, two male participants in the control group were excluded as they were absent from audiometry tests. Elderly participants in the case group were recruited by advertisement on the website of Norwegian University of Science and Technology (Norges Teknisk-Naturvitenskapelige Universitet, NTNU). Younger participants who volunteered for the project were students at NTNU.

The ethical considerations of this study were approved by Norwegian University of Science and

Technology and the Regional Committees for Medical and Health Research Ethics (Regionale Komiteer for Medisinsk og Helsefaglig Forskningsetik, REK 11.08.2022/78016) (Appendix 1 for REK). All participants signed an informed consent prior to the start of data collection (Appendix 2 and 3 for the case and the control groups' consent form, respectively).

Audiometry

The case group and the control group underwent a hearing threshold test at Høresenralen in St. Olav's Hospital and Tunga campus at NTNU, respectively. The audiometry conducted in both these locations used identical guidelines and the tests were carried out by the specialists in audiology. The participants took their tests on different dates, as per their availability. The test was conducted in a quiet room and the participants were instructed to press a signal button when they perceived the auditory cues through the headsets. Each ear was tested on one side at a time at hearing frequencies from 125 to 8000 Hz (125, 250, 500, 1k, 2k, 4k, and 8k Hz). This identified the lowest pitches that could be heard by participants (at least fifty percent accuracy of the times in decibels (dB) of each frequency). To determine the hearing threshold levels on each side, measured values at four frequencies (500, 1k, 2k, and 4k Hz) were calculated as an average. The average of those frequencies, referred to as the Pure Tone Average (PTA), was used for the evaluation of hearing threshold levels of the participants. The PTA threshold for normal hearing is less than 20 dB HL in the better ear. A threshold greater than or equal to 20 dB HL is considered as hearing deficit according to the hearing impairment categories from the GBD group (Stevens et al., 2013).

Postural Stability Measures

Postural sway variables during quiet standing were obtained by using a force platform (Kistler, Type 9286B, 600x400x35mm, 17.5kg, Switzerland). The force plate detects vectors in three dimensions: anterior-posterior (AP), medial-lateral (ML), and vertical components (Fx, Fy, Fz). Outcome variables derived from center of pressure (CoP) were collected as the total mean velocity, AP mean velocity, and ML mean velocity. CoP velocity variables have been denoted to produce a better relative intrasession reliability compared to other variables (Caballero et al., 2015; Li et al., 2016). Data was collected with a sampling frequency of 200 Hz during 75 seconds for each trial.

Test protocol

Prior to collecting force plate data, the participants measured their height and weight. The weight was applied to the force plate as newton (N). If they wore glasses in daily life, it was allowed for them to wear them in the tests. The participants were instructed to step onto the force plate by placing their feet parallel to the lines on the plate spaced 14cm in width between feet, cross their arms over the chest, and look at a marked point (blue asterisk shape,1.80m height, 3.70m distance from the force plate) on the wall.

The baseline trial for the tests was to stand on the force plate for 75 seconds while fixing the gaze upon the marked point. In total, 12 trials were conducted for quiet standing tests with different sensory modulations.

The trials were divided into two sets. One was tested within a normal sound environment without any sound manipulations, the other one was with wearing headsets to suppress sound input from surroundings (Table 1). The baseline tests were carried out twice; at the beginning and at the end of each test set in order to reduce the bias which might be derived from the participants' psychological stress or tension in the lab. Each baseline trial was presented without finding a mean value. The order of trials with sensory modulations were randomized to prevent the learning effect. Six trials with normal sound environment were conducted first, and the same trials were repeated with wearing headsets after 1 minute rest. Table 2 shows examples of randomized order of the test.

Table 1. Balance test conditions and labeled name.

Test Conditions	Labeled name	Test Conditions	Labeled name
1. Eyes-opened with normal sound environment 1	Eo1on	Eyes-opened with sound suppression 1	Eo1off
2. Eyes-closed with normal sound environment	Econ	Eyes-closed with sound suppression	Ecoff
3. Soft surface with normal sound environment	Padon	Soft surface with sound suppression	Padoff
4. Extra sound with normal sound environment	Soundon	Extra sound with sound suppression	Soundoff
5. Cognitive task with normal sound environment	Counton	Cognitive task with sound suppression	Countoff
6. Eyes-opened with normal sound environment 2	Eo2on	Eyes-opened with sound suppression 2	Eo2off

1. Eo1on: the first baseline trial with eyes-opened on the force plate within normal sound condition; **Eo1off**: the first baseline trial with suppressed sound inputs with headsets; **2. Econ**: eyes-closed on the force plate within normal sound condition; **Ecoff**: eyes-closed with suppressed sound inputs with headsets; **3. Padon**: standing on the balance pad with eyes-opened within normal sound condition; **Padoff**: standing on the balance pad with eyes-opened with suppressed sound inputs with headsets; **4. Soundon**: standing on the force plate with eyes-opened with extra sound cues (pink noise) from a loudspeaker; **Soundoff**: standing on the force plate with eyes-opened with extra sound cues (pink noise) from a loudspeaker and the sound of surroundings was suppressed with headsets; **5. Counton**: standing on the force plate with eyes-opened with the counting task within normal sound conditions; **Countoff**: standing on the force plate with eyes-opened with the counting task with suppressed sound inputs with headsets. **6. Eo2on**: the last baseline trial with eyes-opened on the force plate within normal sound condition; **Eo2off**: the last baseline trial but with suppressed sound inputs with headsets.

Table 2. Randomized order of the trials.

A	B	C	D	E	F	G
1,2,3,4,5,6	1,3,2,4,5,6	1,4,5,2,3,6	1,2,5,3,4,6	1,5,2,3,4,6	1,4,3,2,5,6	1,3,5,2,4,6

AIREX® balance-pad (500x410x60mm, 700g, Switzerland) was used for the padon/off conditions on the force plate. The foot position was marked similarly as on the force plate (14cm widthwise). A loudspeaker (Avantone Pro Mixcube Active, 6.5" x 6.5" x 6.5", USA), placed 1 m behind the participant standing on the force plate, provided extra sound information using lower frequencies, ranging from 100 Hz to 4 kHz, referred to as pink noise. These extra sound cues were adjusted to around 55 dB sound pressure level (SPL) for each participant by measuring the sound level right next to the participants' right-side ear with a sound level meter (model: ACT 1345, measuring range: low 30 – 100dB, high 60 – 130dB (A & C), 210x55x32mm, UK). The cognitive task used in the test was to count out loud down from 400 in decrements of 7 for as many counts as possible for the participants during the 75 seconds. This reduced talking and the risk of rhythmic counting which could have an influence on postural control and pattern of sway.

All participants were informed that they could cease the test anytime and for any circumstances. To prevent accidents such as falling during the test, eyes-closed tests were only conducted on the firm surface. Blindfold was not used during the eyes-closed trials as it may have impaired a response if the participant was about to fall. To safeguard against falls, two lab assistants stood close by the participant, particularly for the eyes-closed tests, and the tester held the balance-pad when the participants stepped onto and down from it to prevent risk of slipping. When any mistakes occurred, for example if the participants mispositioned their feet or opened their eyes during the eyes-closed tests, the trial was repeated. Instructions were issued in English and had been used in the lab if participants were fluent in English. For participants not fluent in English, instructions were conducted in Norwegian to avoid miscommunication.

Data Management

Data was safely stored on the NTNU server. Any identifiable data, such as participant name, was modified to an identification number and the scrambling key was saved in a separate place accessible only to the master student. Only people who had been working on this research could access the data.

Data Analysis

MATLAB R2020a was used to process the mean sway velocity variables. The first 10 seconds and the last 5 seconds of sampling duration where the participants stepped on and off the force plate, respectively, were eliminated. During quite standing the first 10 seconds when the person is settling into the stance position and the final seconds for preparation to step off the plate will contain information from the force plate not representing quiet standing. CoP variables were collected with a sampling frequency of 200 Hz. A 5-point differentiation filter was used to calculate velocity from CoP data. Low pass Butterworth filter with a cutoff frequency of 8 Hz and an order of 8 was applied to the velocity variables.

Statistical Analysis

Statistical analysis was conducted with IBM SPSS 28th version. As the number of participants was less than thirty in each group (10 for the case group, 12 for the control group), sway velocity outcome variables were tested for their normality. The results indicated that 36 out of 72 variables were not normally distributed (Shapiro-wilk $p < 0.05$). Nonetheless, parametric tests were chosen for all outcome variables as non-parametric tests could not estimate both between and within subject effects for repeated measures. An independent t-test was performed to confirm the difference of hearing acuity in each ear between the two groups. To ascertain adverse effects of age-related hearing deterioration on postural stability, data was analyzed with a two-way repeated measures general linear model (GLM) with a between-subject factor of the age groups (aged 60-70 years / aged 20-30 years) and within-subject factors of sound conditions (normal sound information without wearing headsets / suppressed sound information with headsets) while standing with various test conditions (baseline trials, eyes-closed, on the balance pad, with provision of pink noise, counting task). All velocity variables were compared between the groups by estimating marginal means with univariate tests and the size of between-subjects effects using partial eta squared ($\eta 2$). All variables without and with headsets were compared within-subjects to investigate the impacts of sound suppression on postural control in each group. Wearing glasses and gender were considered as covariates. Post hoc pairwise comparisons for between-subjects and within-subjects were adjusted with the Bonferroni correction when significant effects between the factors and outcome variables were found. All three sway velocity variables, which consisted of the total mean velocity, AP mean velocity, and ML mean velocity were shown to violate ($p < .001$) the sphericity tests, thus Greenhouse-Geisser correction was used to adjust data inequality.

3. Result

A total of 22 participants were included in this study. The demographics of each group are presented in Table 3. The independent t-test showed that the mean PTA threshold difference in each ear between the two groups were statistically significant (right ear: $t_{20} = 10.579$, $p < .001$, 95% CI = 15.668 - 23.365, left ear: $t_{20} = 10.218$, $p < .001$, 95% CI = 16.925 - 25.608). The mean PTA thresholds in the case group were 19.517dB higher for the right ear and 21.267dB higher for the left ear compared to the control group ($p < .001$).

Table 3. Demographics of each group.

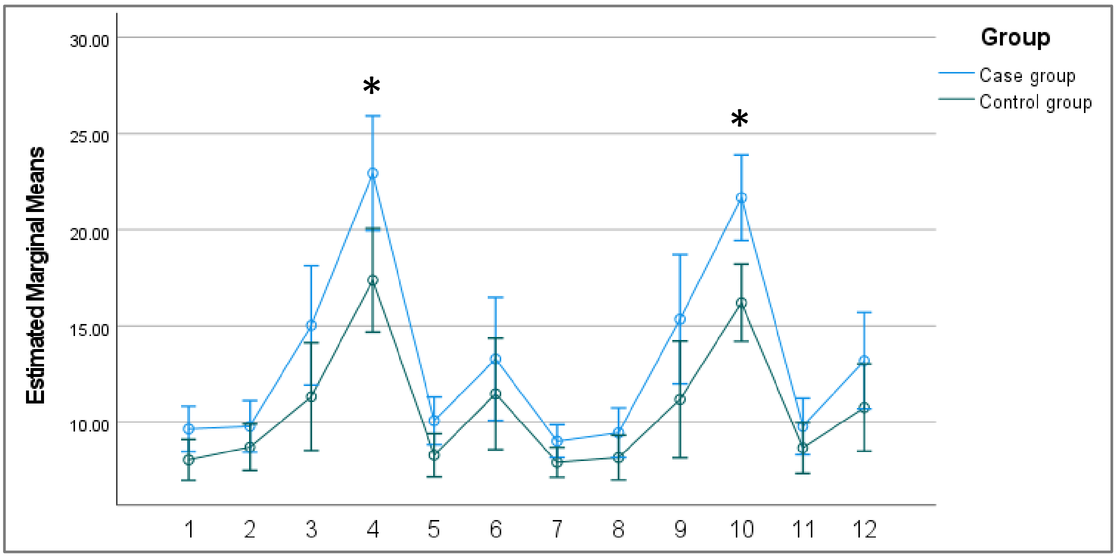
Group	N	Gender (Male: Female)	Mean age (SD)	Mean height cm, (SD)	Mean weight kg, (SD)	Mean PTA right ear dB HL, (SD)	Mean PTA left ear dB HL, (SD)	Wearing glasses (Yes: No)
Case	10	4:6	65.8 (3.3)	171.7 (8.3)	76.8 (17.8)	20.6 (5.3)	21.1 (6.2)	5:5
Control	12	2:10	22.8 (2.6)	167.6 (10.8)	66.1 (15.3)	1.08 (3.3)	-0.2 (3.3)	2:10

Inter-group differences in mean total sway velocity

GLM repeated measures evaluated total sway velocity differences between the groups for 12 test trials. The results of univariate tests demonstrated significant between-subjects effects of sway velocity variables ($F_{1, 18} = 5.513$; $p = 0.031$, $\eta 2 = 0.234$). The results of pairwise comparisons for mean total sway velocity between the groups showed that the group mean difference was 2.6 mm/s ($p = 0.031$, SE = 1.104, 95% CI = 0.273 - 4.913).

Figure 1 below shows the group differences of sway velocity variables in each test trial for total sway velocity. The mean difference of sway velocity between two groups in each test condition was estimated by the pairwise tests from GLM repeated measures (Table 4). The results exhibited that the case group had higher velocity outcomes in all conditions than the control group. Significant group differences were however, only found with somatosensory modulation with and without sound cues in univariate test results (with sound: $F_{1,18} = 6.91$, $p = 0.017$, $\eta 2 = 0.28$; without sound: $F_{1,18} = 12.03$, $p = 0.003$, $\eta 2 = 0.40$).

Figure 1. Mean sway velocity differences between the case and control groups in each trial.



*: Significant mean difference at the .05 level. Error bars indicate ±2 standard error (SE). Glasses and gender were evaluated as covariate values of 0.32, and 1.7, respectively. **1) eo1on:** the first baseline trial with eyes-opened on the force plate within normal sound condition; **2) eo2on:** the last baseline trial with eyes-opened on the force plate within normal sound condition; **3) econ:** eyes-closed on the force plate within normal sound condition; **4) padon:** standing on the balance pad with eyes-opened within normal sound condition; **5) soundon:** standing on the force plate with eyes-opened with provision of pink noise from the loudspeaker; **6) counton:** standing on the force plate with eyes-opened with the counting task within normal sound conditions; **7) eo1off**: the first baseline trial with suppressed sound inputs with headsets; **8) eo2off:** the last baseline trial with suppressed sound inputs with headsets; **9) ecoff:** eyes-closed with suppressed sound inputs with headsets; **10) padoff:** standing on the balance pad with eyes-opened with suppressed sound inputs with headsets; **11) soundoff:** standing on the force plate with eyes-opened with provision of pink noise from the loud speaker with suppressed sounds with headsets; **12) countoff:** standing on the force plate with eyes-opened with the counting task with suppressed sound inputs with headsets.

Table 4. Estimated mean outcomes of total sway velocity and the difference between the groups.

	Case Group (N=10)	Control Group (N=12)	Total (N=22)				95% CI
Test conditions (Total velocity)	M (SE)	M (SE)	Mean Difference	$F_{1, 18}$	p-value	η2	Lower / Upper
Eo1on	9.65 (0.59)	8.04 (0.53)	1.61	3.71	0.070	0.17	-0.15 / 3.36
Eo2on	9.79 (0.67)	8.70 (0.60)	1.08	1.30	0.268	0.07	-0.91 / 3.07
Econ	15.03 (1.55)	11.32 (1.40)	3.71	2.86	0.108	0.14	-0.90 / 8.32
Padon*	22.93 (1.49)	17.38 (1.35)	5.55	6.91	0.017	0.28	1.12 / 9.99
Soundon	10.08 (0.62)	8.29 (0.56)	1.79	4.18	0.056	0.19	-0.05 / 3.62
Counton	13.29 (1.60)	11.47 (1.45)	1.81	0.64	0.434	0.03	-2.95 / 6.58
Eo1off	9.02 (0.43)	7.92 (0.39)	1.10	3.32	0.085	0.16	-0.17 / 2.37
Eo2off	9.46 (0.64)	8.16 (0.58)	1.29	2.00	0.173	0.10	-0.62 / 3.20
Ecoff	15.35 (1.68)	11.18 (1.51)	4.17	3.09	0.096	0.15	-0.82 / 9.16
Padoff*	21.67 (1.11)	16.21 (1.00)	5.46	12.03	0.003	0.40	2.15 / 8.77
Soundoff	9.78 (0.73)	8.67 (0.66)	1.11	1.15	0.297	0.06	-1.06 / 3.29
Countoff	13.19 (1.25)	10.76 (1.13)	2.44	1.88	0.187	0.10	-1.29 / 6.16

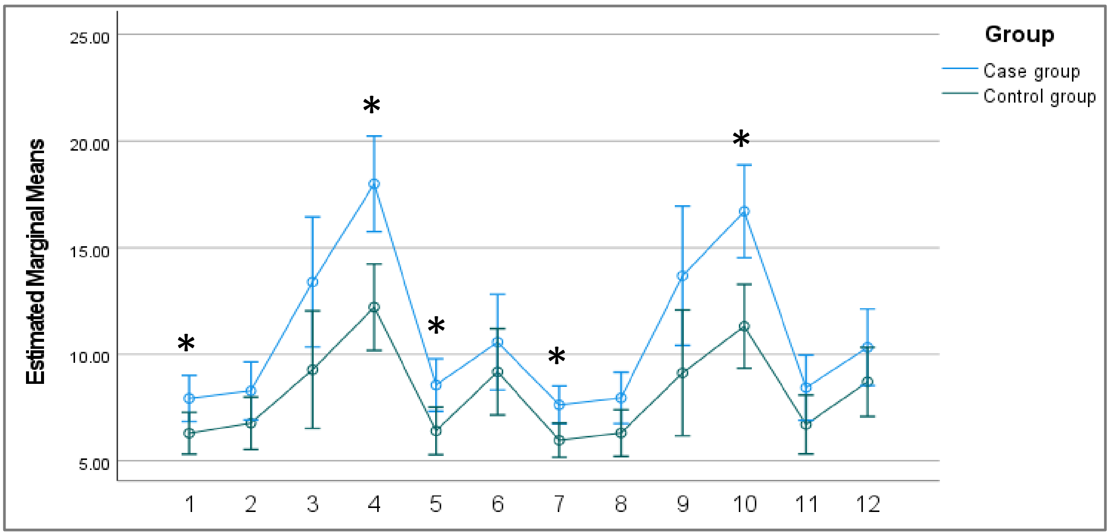
The mean difference was calculated by subtracting outcomes of the control group from the case group. *: Significant mean difference at the .05 level. 95% CI indicates 95% confidence interval for mean difference. η2 = partial eta squared. **Eo1on:** the first baseline trial with eyes-opened on the force plate within normal sound condition; **Eo2on:** the last baseline trial with eyes-opened on the force plate within normal sound condition; **Econ:** eyes-closed on the force plate within normal sound condition; **Padon:** standing on the balance pad with eyes-opened within normal sound condition; **Soundon:** standing on the force plate with eyes-opened with provision of pink noise from the loudspeaker; **Counton:** standing on the force plate with eyes-opened with the counting task within normal sound conditions; **Eo1off**: the first baseline trial with suppressed sound inputs with headsets; **Eo2off:** the last baseline trial with suppressed sound inputs with headsets; **Ecoff:** eyes-closed with suppressed sound inputs with headsets; **Padoff:** standing on the balance pad with eyes-opened with suppressed sound inputs with headsets; **Soundoff:** standing on the force plate with eyes-opened with provision of pink noise with suppressed sounds with headsets; **Countoff:** standing on the force plate with eyes-opened with the counting task with suppressed sound inputs with headsets.

Inter-group differences in anterior-posterior and medial-lateral velocity

There were significant group differences in the AP velocity results analyzed by univariate tests of the GLM repeated measure ($F_{1, 18} = 6.744$; $p = 0.018$, $\eta 2 = 0.273$). On the other hand, the groups did not show statistically significant differences in ML velocity results ($F_{1, 18} = 0.303$; $p = 0.588$, $\eta 2 = 0.017$). According to the univariate tests between the groups, the differences of the mean AP velocity and ML velocity values were 2.8 mm/s (p = 0.018, SE = 1.065, 95% CI = 0.528 - 5.003) and 0.3 mm/s (p = 0.588, SE = 0.529, 95% CI = -0.819 - 1.402), respectively. The group differences of AP and ML velocity are presented in Figure 2 and Figure 3.

As a result of the univariate tests in pairwise comparisons, the AP velocity between the two groups significantly differed for the first baseline test and standing on the balance pad in both sound conditions (Table 5). For the first baseline test, the significance was $F_{1,18} = 4.58$, $p = 0.046$, $\eta 2 = 0.20$ with normal sound, and $F_{1,18} = 6.99$, $p = 0.016$, $\eta 2 = 0.28$ with restricted sound. The significance of the between group difference with the balance pad trial was $F_{1,18} = 13.29$, $p = 0.002$, $\eta 2 = 0.43$ within the normal sound environment, and $F_{1,18} = 12.17$, $p = 0.003$, $\eta 2 = 0.40$ with sound suppression. Provision of pink noise also showed a significant group difference, when the participants did not wear headsets ($F_{1,18} = 6.08$, $p = 0.024$, $\eta 2 = 0.25$). In contrast, none of the test trials showed significant differences between the case and the control group in the ML directions from pairwise comparisons and univariate test results (Table 6).

Figure 2. Anterior-posterior velocity differences between the case and the control groups in each trial.



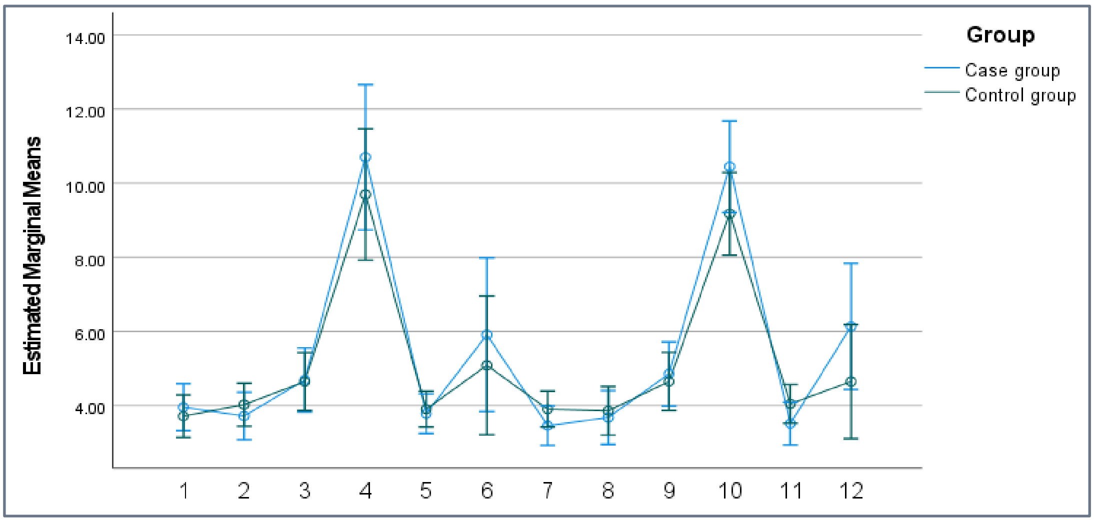
*: Significant mean difference at the .05 level. Error bars indicate ±2 standard error (SE). Glasses and gender were evaluated as covariate values of 0.32, and 1.7, respectively. **1) eo1on:** the first baseline trial with eyes-opened on the force plate within normal sound condition; **2) eo2on:** the last baseline trial with eyes-opened on the force plate within normal sound condition; **3) econ:** eyes-closed on the force plate within normal sound condition; **4) padon:** standing on the balance pad with eyes-opened within normal sound condition; **5) soundon:** standing on the force plate with eyes-opened with provision of pink noise from the loudspeaker; **6) counton:** standing on the force plate with eyes-opened with the counting task within normal sound conditions; **7) eo1off**: the first baseline trial with suppressed sound inputs with headsets; **8) eo2off:** the last baseline trial with suppressed sound inputs with headsets; **9) ecoff:** eyes-closed with suppressed sound inputs with headsets; **10) padoff:** standing on the balance pad with eyes-opened with suppressed sound inputs with headsets; **11) soundoff:** standing on the force plate with eyes-opened with provision of pink noise from the loud speaker with suppressed sounds with headsets; **12) countoff:** standing on the force plate with eyes-opened with the counting task with suppressed sound inputs with headsets.

Table 5. Estimated mean outcomes of anterior-posterior sway velocity and the difference between the groups.

	Case Group (N=10)	Control Group (N=12)	Total (N=22)				95% CI
Test conditions (AP velocity)	M (SE)	M (SE)	Mean Difference	$F_{1, 18}$	p-value	η2	Lower / Upper
Eo1on*	7.93 (0.54)	6.30 (0.49)	1.64	4.58	0.046	0.20	0.03 / 3.25
Eo2on	8.29 (0.68)	6.77 (0.61)	1.51	2.48	0.133	0.12	-0.51 / 3.53
Econ	13.40 (1.52)	9.28 (1.38)	4.12	3.64	0.073	0.17	-0.42 / 8.65
Padon*	18.00 (1.12)	12.21 (1.01)	5.79	13.29	0.002	0.43	2.45 / 9.12
Soundon*	8.56 (0.62)	6.41 (0.56)	2.15	6.08	0.024	0.25	0.32 / 3.99
Counton	10.57 (1.12)	9.18 (1.02)	1.39	0.76	0.393	0.04	-1.95 / 4.73
Eo1off*	7.63 (0.44)	5.97 (0.40)	1.66	6.99	0.016	0.28	0.34 / 2.98
Eo2off	7.96 (0.60)	6.31 (0.55)	1.65	3.71	0.070	0.17	-0.15 / 3.44
Ecoff	13.69 (1.63)	9.13 (1.47)	4.56	3.89	0.064	0.18	-0.30 / 9.41
Padoff*	16.71 (1.09)	11.32 (0.99)	5.39	12.17	0.003	0.40	2.14 / 8.63
Soundoff	8.44 (0.76)	6.71 (0.69)	1.73	2.54	0.128	0.12	-0.55 / 4.00
Countoff	10.33 (0.90)	8.71 (0.81)	1.62	1.62	0.220	0.08	-1.06 / 4.30

The mean difference was calculated by subtracting outcomes of the control group from the case group. *: Significant mean difference at the .05 level. 95% CI indicates 95% confidence interval for mean difference. η2 = partial eta squared. **Eo1on:** the first baseline trial with eyes-opened on the force plate within normal sound condition; **Eo2on:** the last baseline trial with eyes-opened on the force plate within normal sound condition; **Econ:** eyes-closed on the force plate within normal sound condition; **Padon:** standing on the balance pad with eyes-opened within normal sound condition; **Soundon:** standing on the force plate with eyes-opened with provision of pink noise from the loudspeaker; **Counton:** standing on the force plate with eyes-opened with the counting task within normal sound conditions; **Eo1off**: the first baseline trial with suppressed sound inputs with headsets; **Eo2off:** the last baseline trial with suppressed sound inputs with headsets; **Ecoff:** eyes-closed with suppressed sound inputs with headsets; **Padoff:** standing on the balance pad with eyes-opened with suppressed sound inputs with headsets; **Soundoff:** standing on the force plate with eyes-opened with provision of pink noise with suppressed sounds with headsets; **Countoff:** standing on the force plate with eyes-opened with the counting task with suppressed sound inputs with headsets.

Figure 3. Medial-lateral velocity differences between the case and the control groups in each trial.



Error bars indicate ±2 standard error (SE). Glasses and gender were evaluated as covariate values of 0.32, and 1.7, respectively. **1) eo1on:** the first baseline trial with eyes-opened on the force plate within normal sound condition; **2) eo2on:** the last baseline trial with eyes-opened on the force plate within normal sound condition; **3) econ:** eyes-closed on the force plate within normal sound condition; **4) padon:** standing on the balance pad with eyes-opened within normal sound condition; **5) soundon:** standing on the force plate with eyes-opened with provision of pink noise from the loudspeaker; **6) counton:** standing on the force plate with eyes-opened with the counting task within normal sound conditions; **7) eo1off**: the first baseline trial with suppressed sound inputs with headsets; **8) eo2off:** the last baseline trial with suppressed sound inputs with headsets; **9) ecoff:** eyes-closed with suppressed sound inputs with headsets; **10) padoff:** standing on the balance pad with eyes-opened with suppressed sound inputs with headsets; **11) soundoff:** standing on the force plate with eyes-opened with provision of pink noise from the loud speaker with suppressed sounds with headsets; **12) countoff:** standing on the force plate with eyes-opened with the counting task with suppressed sound inputs with headsets.

Table 6. Estimated mean outcomes of medial-lateral sway velocity and the difference between the groups.

Test conditions (ML velocity)	Case Group (N=10) M (SE)	Control Group (N=12) M (SE)	Total (N=22) Mean Difference	$F_{1, 18}$	p-value	η2	95% CI Lower / Upper
Eo1on	3.95 (0.32)	3.71 (0.29)	0.24	0.29	0.597	0.02	-0.70 / 1.19
Eo2on	3.72 (0.32)	4.02 (0.29)	-0.30	0.46	0.507	0.03	-1.26 / 0.65
Econ	4.69 (0.43)	4.64 (0.39)	0.05	0.006	0.942	0.00	-1.24 / 1.33
Padon	10.70 (0.98)	9.70 (0.89)	1.01	0.52	0.479	0.03	-1.92 / 3.93
Soundon	3.78 (0.27)	3.90 (0.24)	-0.12	0.11	0.748	0.01	-0.92 / 0.67
Counton	5.91 (1.04)	5.08 (0.94)	0.83	0.32	0.580	0.02	-2.26 / 3.91
Eo1off	3.46 (0.27)	3.90 (0.24)	-0.45	1.39	0.253	0.07	-1.24 / 0.35
Eo2off	3.67 (0.36)	3.86 (0.33)	-0.18	0.12	0.728	0.01	-1.26 / 0.90
Ecoff	4.85 (0.43)	4.65 (0.39)	0.21	0.11	0.741	0.01	-1.08 / 1.50
Padoff	10.45 (0.62)	9.18 (0.56)	1.27	2.11	0.164	0.11	-0.57 / 3.11
Soundoff	3.51 (0.29)	4.05 (0.26)	-0.53	1.70	0.209	0.09	-1.39 / 0.33
Countoff	6.13 (0.85)	4.65 (0.77)	1.49	1.52	0.233	0.08	-1.05 / 4.02

The mean difference was calculated by subtracting outcomes of the control group from the case group. The mean difference is significant at the .05 level. 95% CI indicates 95% confidence interval for mean difference. η2 = partial eta squared. **Eo1on:** the first baseline trial with eyes-opened on the force plate within normal sound condition; **Eo2on:** the last baseline trial with eyes-opened on the force plate within normal sound condition; **Econ:** eyes-closed on the force plate within normal sound condition; **Padon:** standing on the balance pad with eyes-opened within normal sound condition; **Soundon:** standing on the force plate with eyes-opened with provision of pink noise from the loudspeaker; **Counton:** standing on the force plate with eyes-opened with the counting task within normal sound conditions; **Eo1off**: the first baseline trial with suppressed sound inputs with headsets; **Eo2off:** the last baseline trial with suppressed sound inputs with headsets; **Ecoff:** eyes-closed with suppressed sound inputs with headsets; **Padoff:** standing on the balance pad with eyes-opened with suppressed sound inputs with headsets; **Soundoff:** standing on the force plate with eyes-opened with provision of pink noise with suppressed sounds with headsets; **Countoff:** standing on the force plate with eyes-opened with the counting task with suppressed sound inputs with headsets.

Within-subjects effect of sound information on postural stability in each group.

The results of within-subjects effects, from a two-way repeated measures GLM with a Greenhouse-Geisser correction, indicated that there was no significant effect of sound conditions on the sway velocity variables for the groups. Only in AP directions, the outcomes of various test trials had a significant effect on the groups ($F_{2.785,50.121} = 3.799$, $p = 0.018$, $\eta 2 = 0.174$), but sound conditions did not affect the groups. Table 7 shows the result of pairwise comparison between the sound conditions within the groups. In general, within-subject comparisons showed that sways were faster within normal sound conditions than suppressed sounds, but the case group showed an increased velocity when the visual and sound inputs were simultaneously restrained. However, those changes were not significant.

Table 7. Mean velocity outcomes with normal sound and suppressed sound conditions and the difference of velocity variables between sound and without sound conditions in each group.

	Case group			Control group		
	Mean		Difference	Mean		Difference
	Normal (SE)	Suppressed (SE)	Difference (p-value)	Normal (SE)	Suppressed (SE)	Difference (p-value)
Total velocity (mm/s)						
Eo1	9.65 (0.59)	9.02 (0.43)	0.63 (0.71)	8.04 (0.53)	7.92 (0.39)	0.12 (0.68)
Eo2	9.79 (0.67)	9.45 (0.64)	0.33 (0.55)	8.71 (0.60)	8.16 (0.58)	0.54 (0.29)
EC	15.03 (1.55)	15.35 (1.68)	-0.32 (0.63)	11.32 (1.40)	11.18 (1.52)	0.15 (0.81)
Pad	22.93 (1.49)	21.67 (1.11)	1.27 (0.32)	17.38 (1.35)	16.21 (1.00)	1.17 (0.30)
Extra sound	10.08 (0.62)	9.78 (0.73)	0.30 (0.52)	8.29 (0.56)	8.67 (0.66)	-0.38 (0.37)
Count	13.29 (1.60)	13.19 (1.25)	0.09 (0.90)	11.47 (1.45)	10.76 (1.13)	0.71 (0.26)
AP velocity (mm/s)						
Eo1	7.93 (0.54)	7.63 (0.44)	0.31 (0.30)	6.30 (0.49)	5.97 (0.40)	0.33 (0.23)
Eo2	8.29 (0.68)	7.96 (0.60)	0.33 (0.46)	6.77 (0.61)	6.31 (0.55)	0.46 (0.25)
EC	13.40 (1.52)	13.69 (1.63)	-0.29 (0.62)	9.30 (1.38)	9.13 (1.47)	0.15 (0.77)
Pad	18.00 (1.12)	16.71 (1.09)	1.29 (0.19)	12.21 (1.01)	11.32 (0.99)	0.89 (0.31)
Extra sound	8.56 (0.62)	8.44 (0.76)	0.12 (0.76)	6.41 (0.56)	6.71 (0.69)	-0.30 (0.40)
Count	10.57 (1.12)	10.33 (0.90)	0.24 (0.65)	9.18 (1.02)	8.71 (0.81)	0.47 (0.34)
ML velocity (mm/s)						
Eo1	3.95 (0.32)	3.46 (0.27)	0.50 (0.06)	3.71 (0.29)	3.90 (0.24)	-0.19 (0.40)
Eo2	3.72 (0.32)	3.67 (0.36)	0.04 (0.89)	4.02 (0.29)	3.86 (0.33)	0.17 (0.55)
EC	4.69 (0.43)	4.85 (0.43)	-0.17 (0.61)	4.64 (0.39)	4.65 (0.39)	0.00 (0.99)
Pad	10.70 (0.98)	10.45 (0.62)	0.26 (0.74)	9.70 (0.89)	9.18 (0.56)	0.52 (0.46)
Extra sound	3.78 (0.27)	3.51 (0.29)	0.27 (0.38)	3.90 (0.24)	4.05 (0.26)	-0.15 (0.59)
Count	5.91 (1.04)	6.13 (0.85)	-0.23 (0.59)	5.08 (0.94)	4.65 (0.77)	0.44 (0.26)

Normal: normal sound environments without any sound manipulation; **Suppressed:** Suppressed sound inputs with headsets; **Eo1:** the first base line test; **Eo2:** the last baseline test; **EC:** eyes-closed; **Pad:** standing on the balance pad; **Extra sound:** extra sound inputs with pink noise; **Count:** standing on a force plate with a counting task. **AP:** anterior-posterior, **ML:** medial-lateral.

Effects of sensory modulations on sway velocity within different sound conditions in the case group.

Table 8 shows the pairwise test results of total, AP, and ML mean sway velocity, respectively, which compared each test condition to the baseline trials within different sound conditions (normal / suppressed) in the case group. In comparison with baseline trials, pink noise provided by the loudspeaker had no significant effect on any of the sway velocity variables for the case group. Total and AP sway velocity in the case group increased in eyes-closed and standing on the balance pad conditions with both normal sound and suppressed sound environments. When sound information was suppressed by wearing headsets, the counting task aggravated total and AP sway velocity compared to the first baseline trial for the case group. However, the significant effect of the counting task on sway velocity for the case group was only shown in a comparison with the first baseline tests with suppressed sound environments.

In the ML directions, the application of balance pad significantly affected postural control for the case group regardless of the sound conditions. Within the suppressed sound conditions, the eyes-closed task for the case group increased ML sway velocity but within normal sound environments, no significant change occurred. The counting task did not affect sway velocity for the case groups in ML direction.

Effects of sensory modulations on sway velocity within different sound conditions in the control group.

Table 9 shows the results of pairwise comparison between the baseline trials and each test trial with different sensory modulations within different sound conditions (normal / suppressed) in total, AP, and ML sway velocity in the control group. The same as in the case group, provision of extra sound cues had no significant influence on any of sway velocity variables for the control group compared to the baseline trials. There was no significant effect on total and AP sway velocity during the eyes-closed task for the control group in either normal or suppressed sound conditions. Standing on the balance pad, regardless of sound conditions, significantly increased total, AP, and ML sway velocity in the control group. The AP sway velocity was significantly increased with the counting task when the sound inputs were suppressed for the control group in comparison with the first and the last baseline tests. The counting task showed no significance compared to the baseline trials in total and ML sway velocity for the control group. In the ML directions, the mean difference between the first baseline trial and with eyes-closed task within normal sound environments indicated significance in the control group.

Table 8. Sway velocity comparisons between baseline tests and each trial with sensory modulations in the case group.

Sway variables	Sound	Test condition (I)	Test condition (J)	Mean Difference (I-J)	Std. Error	Sig.	95% CI for Difference Lower Bound	Upper Bound
Total sway velocity	Normal sound	Baseline1	Eyes-closed*	-5.38	1.17	.003	-9.33	-1.44
			Pad*	-13.28	1.39	<.001	-17.97	-8.59
			Extra sound	-0.43	0.48	1.00	-2.04	1.19
			Count	-3.64	1.52	.420	-8.78	1.51
		Baseline 2	Eyes-closed *	-5.25	1.14	.003	-9.11	-1.39
			Pad*	-13.15	1.40	<.001	-17.88	-8.41
			Extra sound	-0.29	0.54	1.00	-2.13	1.55
			Count	-3.50	1.52	.500	-8.64	1.64
	Suppressed sound	Baseline 1	Eyes-closed *	-6.33	1.40	.004	-11.05	-1.61
			Pad*	-12.65	0.87	<.001	-15.60	-9.69
			Extra sound	-0.76	0.60	1.00	-2.81	1.28
			Count*	-4.18	1.19	.037	-8.19	-0.16
		Baseline2	Eyes-closed *	-5.90	1.21	.002	-10.00	-1.80
			Pad*	-12.21	0.85	<.001	-15.08	-9.34
			Extra sound	-0.33	0.50	1.00	-2.01	1.35
			Count	-3.74	1.17	.074	-7.69	0.21
AP sway velocity	Normal sound	Baseline 1	Eyes-closed *	-5.46	1.13	.002	-9.30	-1.63
			Pad*	-10.06	0.94	<.001	-13.24	-6.88
			Extra sound	-0.63	0.41	1.00	-2.01	0.75
			Count	-2.64	1.07	.364	-6.26	0.99
		Baseline 2	Eyes-closed *	-5.11	1.05	.002	-8.66	-1.56
			Pad*	-9.71	0.96	<.001	-12.97	-6.45
			Extra sound	-0.28	0.47	1.00	-1.87	1.32
			Count	-2.28	1.05	.650	-5.84	1.27
	Suppressed sound	Baseline 1	Eyes-closed *	-6.06	1.30	.003	-10.46	-1.65
			Pad*	-9.08	0.81	<.001	-11.81	-6.35
			Extra sound	-0.81	0.53	1.00	-2.59	0.98
			Count*	-2.70	0.78	.041	-5.33	-0.07
		Baseline 2	Eyes-closed *	-5.73	1.11	.001	-9.50	-1.96
			Pad*	-8.75	0.83	<.001	-11.55	-5.95
			Extra sound	-0.48	0.39	1.00	-1.81	0.85
			Count	-2.37	0.76	.088	-4.94	0.19
ML sway velocity	Normal sound	Baseline 1	Eyes-closed	-0.74	0.25	.130	-1.58	0.11
			Pad*	-6.75	0.93	<.001	-9.90	-3.60
			Extra sound	0.18	0.24	1.00	-0.64	1.00
			Count	-1.96	0.89	.623	-4.97	1.06
		Baseline 2	Eyes-closed	-0.97	0.38	.311	-2.27	0.32
			Pad*	-6.99	0.96	<.001	-10.23	-3.74
			Extra sound	-0.06	0.28	1.00	-1.01	0.89
			Count	-2.19	0.95	.488	-5.40	1.01
	Suppressed sound	Baseline 1	Eyes-closed*	-1.40	0.39	.030	-2.71	-0.09
			Pad*	-6.99	0.60	<.001	-9.02	-4.96
			Extra sound	-0.06	0.31	1.00	-1.10	0.99
			Count	-2.68	0.85	.080	-5.54	0.18
		Baseline 2	Eyes-closed*	-1.18	0.33	.036	-2.31	-0.05
			Pad*	-6.77	0.52	<.001	-8.54	-5.01
			Extra sound	0.16	0.28	1.00	-0.80	1.12
			Count	-2.46	0.80	.101	-5.18	0.26

*: Significant mean difference at the .05 level. **Baseline 1:** The first baseline trial; **Baseline 2:** The last baseline trial. Headsets were utilized for suppressed sound conditions. **Pad:** Standing on the balance pad; **Extra sound:** Provision of

pink noise with a loudspeaker; **Count:** Cognitive task.

Table 9. Sway velocity comparisons between baseline tests and each trial with sensory modulations in the control group.

Sway variables	Sound	Test condition (I)	Test condition (J)	Mean Difference (I-J)	Std. Error	Sig.	95% CI for Difference Lower Bound	95% CI for Difference Upper Bound
Total sway velocity	Normal sound	Baseline1	Eyes-closed	-3.28	1.05	.091	-6.85	0.29
			Pad*	-9.34	1.25	<.001	-13.58	-5.10
			Extra sound	-0.25	0.43	1.00	-1.71	1.22
			Count	-3.43	1.38	.340	-8.08	1.22
		Baseline 2	Eyes-closed	-2.62	1.03	.309	-6.11	0.87
			Pad*	-8.68	1.27	<.001	-12.95	-4.40
			Extra sound	0.42	0.49	1.00	-1.25	2.08
			Count	-2.77	1.37	.890	-7.41	1.88
	Suppressed sound	Baseline 1	Eyes-closed	-3.26	1.26	.283	-7.53	1.01
			Pad*	-8.29	0.79	<.001	-10.95	-5.62
			Extra sound	-0.75	0.55	1.00	-2.60	1.10
			Count	-2.84	1.07	.249	-6.47	0.79
		Baseline2	Eyes-closed	-3.02	1.10	.197	-6.72	0.69
			Pad*	-8.04	0.77	<.001	-10.64	-5.45
			Extra sound	-0.51	0.45	1.00	-2.02	1.01
			Count	-2.60	1.06	.366	-6.17	0.98
AP sway velocity	Normal sound	Baseline 1	Eyes-closed	-2.98	1.03	.141	-6.45	0.48
			Pad*	-5.91	0.85	<.001	-8.79	-3.04
			Extra sound	-0.11	0.37	1.00	-1.36	1.14
			Count	-2.88	0.97	.122	-6.16	0.39
		Baseline 2	Eyes-closed	-2.51	0.95	.249	-5.72	0.70
			Pad*	-5.44	0.87	<.001	-8.38	-2.49
			Extra sound	0.36	0.43	1.00	-1.08	1.81
			Count	-2.41	0.95	.312	-5.62	0.81
	Suppressed sound	Baseline 1	Eyes-closed	-3.16	1.18	.229	-7.14	0.82
			Pad*	-5.35	0.73	<.001	-7.82	-2.88
			Extra sound	-0.74	0.48	1.00	-2.36	0.87
			Count*	-2.74	0.70	.016	-5.12	-0.36
		Baseline 2	Eyes-closed	-2.82	1.01	.178	-6.22	0.59
			Pad*	-5.01	0.75	<.001	-7.54	-2.48
			Extra sound	-0.40	0.36	1.00	-1.61	0.80
			Count*	-2.40	0.69	.039	-4.72	-0.08
ML sway velocity	Normal sound	Baseline 1	Eyes-closed*	-0.93	0.23	.009	-1.70	-0.17
			Pad*	-5.99	0.84	<.001	-8.83	-3.14
			Extra sound	-0.19	0.22	1.00	-0.93	0.55
			Count	-1.37	0.81	1.00	-4.10	1.35
		Baseline 2	Eyes-closed	-0.62	0.35	1.00	-1.79	0.55
			Pad*	-5.67	0.87	<.001	-8.61	-2.74
			Extra sound	0.12	0.25	1.00	-0.73	0.98
			Count	-1.06	0.86	1.00	-3.96	1.84
	Suppressed sound	Baseline 1	Eyes-closed	-0.74	0.35	.710	-1.93	0.44
			Pad*	-5.27	0.54	<.001	-7.11	-3.44
			Extra sound	-0.14	0.28	1.00	-1.09	0.80
			Count	-0.74	0.76	1.00	-3.33	1.84
		Baseline 2	Eyes-closed	-0.79	0.30	.260	-1.81	0.23
			Pad*	-5.32	0.47	<.001	-6.92	-3.72
			Extra sound	-0.19	0.26	1.00	-1.06	0.68
			Count	-0.79	0.73	1.00	-3.25	1.67

*: Significant mean difference at the .05 level. **Baseline 1:** The first baseline trial; **Baseline 2:** The last baseline trial. Headsets were utilized for suppressed sound conditions. **Pad:** Standing on the balance pad; **Extra sound:** Provision of

pink noise with a loudspeaker; **Count:** Cognitive task.

4. Discussion.

The goal of the current study was to investigate the impact of age-related hearing attenuation on postural stability in older adults aged 60-70-years compared to young adults aged 20-30-years. The results demonstrated clear declines in hearing acuity and postural control in the older group. There were significant group differences regarding the effect of sound manipulations on postural control for sway velocity in the AP direction. Provision of pink noise in the normal sound condition and the first baseline trial with headsets for sound suppression also showed significant group differences in AP sway velocity. However, restricted access to sound cues with headsets and provision of pink noise did not show a significant contribution to the changes of postural sway for within-subjects effects. Albeit non-significant, the effect of sound showed decreased sway velocity in the younger adult group, while velocity increased in the older adult group. Thus, it seems that there might be an interaction between effect of auditory information on postural control and effect of group. An indisputable impact of auditory information on postural control was thus not proven in the present study.

The current study suggests that the differences in postural control between the two groups seem to be mainly a result of general age-related changes in the overall sensory systems together with the auditory system. In accordance with within-subjects pairwise comparisons between the baseline and sensory modulation trials, both groups had significant increases in sway velocity when they stood on the balance pad. The mean differences between the groups for balance pad condition were statistically significant in the total and AP velocity results. The first baseline test results in both normal and suppressed sound environments and the presence of pink noise with a normal sound environment also showed significant group differences in AP sway velocity. However, these sound manipulations had no significant effect on postural control within each group in relation to baseline. From these results, our assumption is that postural control was mostly affected by the manipulation of the somatosensory system, and to a greater degree in the older group who had generally poorer postural stability than the younger group, probably depending on that overall sensory acuity attenuates with aging. Postural stability is maintained when the central nervous system integrates the information from the sensory systems and transmits combined information to the motor system (Deliagina et al., 2006; Duarte & de Freitas, 2010, Maki & McIlroy, 1996). Together with hearing acuity, overall sensory systems including visual, vestibular, somatosensory apparatus deteriorate with aging (Maki & McIlroy, 1996). The central nervous system, containing a number of neurons, dendrites, and branching, as well as musculoskeletal system also decrease with aging (Maki & McIlroy, 1996). We assume that these general declines induced by aging affected postural control in the older adults and influenced the differences between the groups in sway velocity in our results.

Our results of the mean group differences in AP sway velocity indicated the significant difference between the groups when the pink noise was presented. In contrast to a previous finding (Ninomiya et al., 2021) which demonstrated that the presence of pink noise decreased sway velocity for both people with normal hearing and hearing aid users, our study indicated that the provision of the extra sound cues provided by a loudspeaker in the room increased sway velocity compared to the baseline trials even though these changes were statistically insignificant, and this tendency clearly showed in the older group in comparison with the younger group. From these results, we surmised that the provision of pink noise in the room in our study may conflict with visual sensory systems because the extra sounds were presented from behind the participants while they gazed at the marked visual point in front of them. On the contrary, Ninomiya et al. (2021) provided auditory cues in front of the test individuals. However, when the sounds of surroundings including pink noise were suppressed by headsets, the postural stability in the older adult group showed an improvement. According to Peterka (2018), when multiple sensory stimuli are relevant and appropriate across the sensory systems in the environment, these consistent and overlapped cues, referred to as sensory redundancy, provide accurate and reliable perception of the body movement in relation to the surroundings and consequently improve balance and mobility. On the contrary, conflicting sensory inputs can generate poor mobility. While an increase or decrease of sensory reliability has a minor impact on younger people, older adults are more likely to be affected by inconsistent sensory information (Campos et al., 2018; de Dieuleveult et al., 2017). Therefore, the opposite directions of visual and auditory cues may disrupt postural control more in the older group than younger group in our study.

In ML velocity, no significant differences between the two groups were found in any of the test conditions. Sway movement from medial to lateral directions during quiet standing with feet parallel is mostly influenced by hip abductor and adductor muscles, and the movement from anterior to posterior directions is controlled by dorsiflexor and plantar muscles on the ankles (Winter et al., 1996). As the stance used in this study was feet side-to-side with a 14cm width, it was unlikely to produce substantial movements to ML directions compared to AP directions.

Contrary to the previous studies (Kanegaonkar et al., 2012; Ninomiya et al., 2021; Viljanen et al., 2009; Vitkovic et al., 2016) where an advantageous effect of sound information on postural control was demonstrated, neither the reduction of acoustic inputs nor the presence of sounds had considerable influence on sway velocity in the younger and older group in the current study. An important factor for consideration for our results however is the acoustic environments used for the tests. Our test room was relatively quiet but not completely insulated against noise. Some irregular sounds occurred inside of the room from the computer devices, and outside of the room such as footsteps might have distracted the participants during the trials. Also, the hearing restriction provided with headsets may not have been efficient enough for total blocking of environmental noise. The general tendency of our results showed that sway velocity decreased when the sound information was suppressed even though the outcomes were not statistically significant. Hence, the irregular noise in the test environment may have impacted postural control during the trials. Further research needs to carefully consider the sounds of surroundings when comparing the impact of acoustic information on balance.

Our study implies that deterioration of hearing develops with aging, and it clearly manifests in people aged 60-70 years. Averaged auditory thresholds in the older adult group of this study were about 20 – 21 dB HL in each ear, which is considered as mild hearing loss according to the GBD group (Stevens et al., 2013). Although our study findings failed to reveal a significant effect of age-related hearing decline on postural control by comparing younger and older adult groups, it showed sway differences between the groups within modified sensory systems conditions. These results imply that overall sensory systems in the human body deteriorate with advancing age, and the adverse changes in the sensory systems may noticeably affect balance. It has been demonstrated that the least sway is generated when congruent multiple sensory stimuli is fully utilized for recognizing orientation of the body (Peterka, 2018). At least one sensory deficit leads to reweighting of the sensory contributions to postural control (Woollacott et al., 1986), and reduced sensory redundancy increases postural sway (Peterka, 2018). Our results indicated that the older adult group had poorer postural control than the younger adult group. This seems because decreased sensory acuity with aging may limit sensory stimuli which can be utilized for postural stabilization. Additionally, when extraneous sensory information is occurring, it can cause poorer performance in older adults compared to younger adults (de Dieuleveult et al., 2017; Woollacott et al., 1986). According to the pairwise comparisons between sound and suppressed sound conditions in the current study, older adults showed increased sway velocity when they were provided pink noise from a loudspeaker, but the sway outcomes were decreased when they wore headsets to suppress the noise from their surroundings including pink noise. Even though these results were statistically insignificant, it may imply that the provision of extra sound cues in our test settings may have caused distraction for the older adult group.

A limitation of our study is the small number of participants and the unbalanced gender ratio in the case and control groups. Even though the gender distribution was applied as a covariate and showed no significant effect on the results, the study outcomes with a small study population are too limited to represent the general population. Another limitation is that the test trials with modulated multisensory conditions appeared too easy for our participants to uncover the effects of auditory cues on postural control caused by sensory reweighting. For example, we only compared the presence of and absence of auditory cues with one particular sensory modulation at a time (i.e., soft surface with hearing / without hearing, eyes-closed with hearing / without hearing and so on). However, if we had adjusted more than one sensory input simultaneously to make the trials more challenging (i.e., closed-eyes on the soft surface with cognitive tasks with normal hearing / closed-eyes on the soft surface with cognitive tasks without hearing), the effect of auditory information on balance and to what degree it might have affected the older versus the younger group may have yielded different results.

Furthermore, our study was limited in terms of verifying ecological validity. One of the ultimate purposes of postural control research is to prevent falling. However, standing on one spot in the rigorously controlled laboratory-based environment cannot reproduce the same conditions as in real-life. Further research reflecting realistic motor functions would enhance the insight of the postural control mechanism in relation to age-related hearing decline in real-life. Another limitation of this study was incomplete sound suppression. As we considered that the older participants might be unfamiliar with earplugs and it might have an impact on test results, we decided to use only headsets instead of using both earplugs and headsets. Thus, the participants might have been able to hear the sounds during the sound suppression tests, and it may have reduced the effect of sound restriction on balance.

The strength of this study is that our main study cohort was the aged between 60-70 years old. Most previous studies regarding hearing and balance tended to focus on the particular characteristics of hearing loss, such as sensorineural, conductive, congenital hearing loss, or hearing aids users. Previous studies regarding age-related hearing attenuation and balance did not specify the age range but specified degrees of hearing loss (Negahban et al., 2017; Vitkovic et al., 2016). Age-related hearing decline is often untreated and overlooked due to the preconception that deterioration of hearing is a normal aging phenomenon (Davis et al., 2016; Wallhagen & Pettengill, 2008), and it is difficult to notice at the early stages of hearing decline, even though about one third of the population aged 60 years and older experiences high frequency hearing loss (Homans et al., 2017). Our research indicated that the study populations aged 60-70 had hearing deterioration and a poorer balance compared to the younger participants who are in their twenties. It implies that age-related alterations have an adverse influence on the sensory systems, and with these sensory declines, postural stability may be easily disturbed by conflicting auditory information together with other sensory sources in older adults. Therefore, the current study may have a meaningful implication to promote attention to hearing with advancing age and its impact on balance, and consequentially on life quality.

5. Conclusion

The present study demonstrated that hearing acuity degenerates along with other sensory and postural control systems in 60-70-year-olds. Our findings suggest that the impact of age-related hearing decline on postural control in 60-70-year-olds is yet equivocal. The older adult group showed increases in sway velocity in general compared to the younger adult group. The mean differences of the outcomes between the groups were most significant with somatosensory modulation, but significant group differences were also found in AP sway velocity with added pink noise and the first baseline trial with suppressed sounds. However, changes in sway velocity within each group by means of sound suppression and the provision of pink noise did not show any significant effect when compared to normal sound conditions and the baseline trials. Although our study contains several limitations, it may have an important implication to provide an insight into the relation between the early stages of hearing decline with aging and postural control seen when examining the 60-70-year-old populations. Further studies with particular age groups, their auditory sense and its effect on postural stability will enhance the awareness of the importance of hearing for older adults.

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Appendix

Appendix 1. REK approval

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK midt	Ramunas Kazakauskas	73597510	27.06.2022	478016

Ann-Katrin Stensdotter

Prosjektsøknad: Balanse hos eldre med hørselstap
Søknadsnummer: 478016
Forskningsansvarlig institusjon: Norges teknisk-naturvitenskapelige universitet
Samarbeidende forskningsansvarlige institusjoner: St. Olavs Hospital HF

Prosjektsøknad godkjennes med vilkår

Søkers beskrivelse

Dette er et tverrfaglig samarbeid mellom audiologi, fysioterapi og bevegelsesvitenskap ved NTNU og høresentralen ved St Olavs Hospital som handler om eldre med hørselstap og balanse. Nyere forskning viser at hørselstap har sammenheng med redusert mobilitet og økt fall risiko, framfor alt hos eldre. Objektive utfallsmål viser nedsatt postural kontroll, spesielt med modulering av sanseinformasjon så som å stå på mykt underlag eller med øyene lukket. Høreapparat (påslått) og lyd virker derimot ha positiv effekt på postural kontroll, imens simulert hørselstap hos normalhørende gir negativ effekt på postural kontroll. Det siste antyder en sammenheng mellom hørsel og postural kontroll uten alders- eller patologisk affeksjon av indreørets organer. En teori er at høreapparat / lyd via stimuli av cochlea senker terskelen i vestibularis (balanseorganet) for registrering av akselerasjon av hodet. En annen teori er at hørsel har funksjon for romsorientering og det spekuleres i om det finnes en «auditory map» for retningssans. Selv om det i siste 10-år har kommet en god del forskning på hørselshemming og postural kontroll gjenstår fortsatt flere spørsmål. Postural kontroll er multisensorisk, men hørsel har ikke tradisjonelt vært inkludert som en essensiell faktor for balanse. I denne studien undersøker vi postural kontroll hos friske eldre med nedsatt hørsel som bruker høreapparat og normalhørende matchede kontrollpersoner, samt en gruppe studenter for sammenligning av aldersrelaterte gruppeforskjeller. Tester av postural kontroll utføres i bevegelseslabb på Øya ved blant annet Rombergtest med ulike kombinasjoner av sansemodulering, lydstimuli og simulert hørselstap hos studentgruppa. Data fra selvrapporterte spørreskjema om hørsel, svimmelhet og fall risiko blir samlet inn og kombinert med objektive utfallsmål fra funksjonstester i bevegelseslabb. Alle studiedeltakere gjennomgår standard hørselstest, samt vestibularis test for både bueganger og otolittorgan.
Forventet resultat er at påslått høreapparat gir bedrer postural kontroll og at lydstimuli forbedrer postural kontroll for alle. Sansemodulering forventes ha større negativ effekt hos de med nedsatt hørsel enn hos normalhørende eldre som igjen får større negativ effekt enn normalhørende yngre.
Resultat fra vår pilotstudie er planlagt å brukes for større søknad om hørselshemming og balanse hos eldre samt basal forskning om mekanismer som forklarer sammenheng mellom hørsel og postural kontroll. Rasjonale for studien er å skape en tverrfaglig forståelse for at hørselstap kan føre til redusert mobilitet og risiko for fall spesielt hos eldre. Studie sikter

også til å legge grunn for tiltak for forebygging.

Innledning
Viviser til dinsøknadom forhåndsgodkjenningavovennevnteforskningsprosjekt.Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikkMidt-Norge (REK midt)i møtet 02.06.2022.Vurderingen er gjort med hjemmel i helseforskningsloven § 10.

REKs vurdering

Komiteens prosjektsammendrag
Formålet med prosjektet er å undersøke hørselstap og balanse. Dette er en pilotstudie, hvor tre grupper deltakere (eldre med hørselstap, eldre uten hørselstap og studenter uten hørselstap), totalt 60 personer, skal gå gjennom tester relatert til balanse på en bevegelseslab, samt besvare spørreskjema. Deltakere med hørselstap rekrutteres gjennom standard kontrollbesøk på Høresentralen, kontroller uten hørselstap rekrutteres gjennom personlige kontakter, mens studenter rekrutteres gjennom studieprogram.

Forsvarlighet
Komiteen har vurdertdin prosjektsøknad. Vi vurderer at det er liten risiko forbundet med deltakelse i studien, og atden er akseptabel gitt den potensielle nyttenav prosjektet. Prosjektet er organisert med en klar ansvarsfordeling, og med relevant og tilstrekkelig kompetanse tilknyttet prosjektet. Under forutsetning av at du tar vilkårene nedenfor til følge vurderer vi at prosjektet er forsvarlig, og at hensynet til deltakernes velferd og integritet er ivaretatt.

Vennligst revider informasjonsskrivet i henhold til følgende punkter:

- Vær nøytral i starten av informasjonsskrivet: Fjern informasjon om nedsatt hørsel og balanse og at det kan føre til risiko og fall.
- Nevn at deltakere kan kontakte fysioterapeut og ellers vil få informasjon om tilbudet Sterk og Stødig.
- Nevn at deltakere kan kontakte Høresentralen for informasjon om testresultatene.
- Beskriv beredskapen som er planlagt i labben.
- Beskriv hvor lang tid deltakelsen tar: testene i labben, å besvare spørreskjema og intervju.
- Fjern de delene som omhandler biologisk materiale på samtykkearket.
- Legg til en avkryssingsboks der deltakerne kan krysse av dersom de samtykker til at kodede opplysninger skal lagres hos Høresentralen. Det er ikke anledning til å lagre deltakernes data uten samtykke til andre formål enn det som er en del av prosjektet.

Vilkår for godkjenning

1. Vi forutsetter at studentene selv tar kontakt med forskere hvis de ønsker å delta.
2. Vi forutsetter at alle deltakerne er samtykkekompetente.
3. Koblingsnøkkel skal ikke oppbevares i journal. Det er kun prosjektleder som skal ha tilgang til denne nøkkelen.
4. Fjern registrering av navn og fødselsnummer fra spørreskjemaene.

5. Vennligst send oss det reviderte informasjonsskrivet. Benytt funksjonen "Endring/henvendelse" i Rekportalen. Studien kan ikke igangsettes før vi har godkjent skrivet.
6. Komiteen forutsetter at ingen personidentifiserbare opplysninger kan framkomme ved publisering eller annen offentliggjøring.
7. Komiteen forutsetter at du og alle prosjektmedarbeiderne følger institusjonens bestemmelser for å ivareta informasjonssikkerhet og personvern ved innsamling, bruk, oppbevaring, deling og utlevering av personopplysninger. Bestemmelsene må være i samsvar med våre vilkår for godkjenning.
8. Av dokumentasjonshensyn skal opplysningene oppbevares i fem år etter prosjektslutt. Enhver tilgang til prosjektdataene skal da være knyttet til behovet for etterkontroll. Prosjektdata vil således ikke være tilgjengelig for prosjektet. Etter denne femårsperioden skal opplysningene slettes eller anonymiseres. Komiteen gjør oppmerksom på at anonymisering er mer omfattende enn å kun slette koblingsnøkkelen, jf. Datatilsynets veileder om anonymiseringsteknikker.

Vedtak
Godkjent med vilkår.

Sluttmelding
Prosjektleder skal sende sluttmelding til REK på eget skjema via REK-portalen senest 6 måneder etter sluttdato 01.06.2023, jf. helseforskningsloven § 12. Dersom prosjektet ikke starter opp eller gjennomføres meldes dette også via skjemaet for sluttmelding.

Søknad om endring
Dersom man ønsker å foreta vesentlige endringer i formål, metode, tidsløp eller organisering må prosjektleder sende søknad om endring via portalen på eget skjema til REK, jf. helseforskningsloven § 11.

Klageadgang
Du kan klage på REKs vedtak, jf. forvaltningsloven § 28 flg. Klagen sendes på eget skjema via REK portalen. Klagefristen er tre uker fra du mottar dette brevet. Dersom REK opprettholder vedtaket, sender REK klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag (NEM) for endelig vurdering, jf. forskningsetikkloven § 10 og helseforskningsloven § 10.

Med vennlig hilsen

Vibeke Videm
Dr. med.
Leder, REK midt

Ramunas Kazakauskas
Rådgiver

Kopi til:

Norges teknisk-naturvitenskapelige universitet
St. Olavs Hospital HF

Appendix 2. An informed consent document for the case group.

The case group is marked as a control group here because a plan for inclusion of participants had to be changed due to the lack of the number of older participants.

NTNU
Faculty of Medicine and Health Sciences

ST. OLAVS HOSPITAL
UNIVERSITETSSYKEHUSET I TRONDHEIM

Vil du delta i forskningsprosjektet BALANSE HOS ELDRE MED HØRSELSTAP?

FORMÅLET MED PROSJEKTET OG HVORFOR DU BLIR SPURT

Dette er et spørsmål til deg om å delta i et forskningsprosjekt som frisk kontrollperson uten hørselstap. Studien handler om hvorvidt og hvordan hørselstap påvirker hverdagen med tanke på mobilitet og balanse. Dette prosjektet er derfor et samarbeid mellom utdanningene for fysioterapi, audiologi, bevegelsesvitenskap ved NTNU og Høresentralen ved St. Olavs hospital. Vi spør derfor deg som har fylt 60 år og ikke har hørselstap eller bruker høreapparat.

HVA INNEBÆRER PROSJEKTET FOR DEG?

Som frisk kontrollperson får du gjennomgå samme tester som deltakere i studien med hørselstap. Ved Høresentralen gjennomgår du derfor standard undersøkelse for hørsel og funksjon av balanse organet som anatomisk er tett knyttet til hørselsorganene. For informasjon om resultat fra disse testene kontakter du Høresentralen.

Du vil også gjennomgå ulike balansetest i bevegelseslabben ved NTNU som ligger i samme bygg som Høresentralen. Det ene testet innebærer å gå innendørs i ett minutt, det andre kalles Romberg der du står i ro i 60 sekunder. Romberg testes med øyene åpne, lukket og stående på et mykt underlag, samt med ulike lyd i rommet og via hodetelefon. Et rekkverk finnes for balansestøtte. For din sikkerhet vil det alltid være to personer til stede i labbet. Dette testet tar ca 30 minutter.

Du fyller også i tre korte spørreskjema om hørsel, svimmelhet og balanse. Tid ca 20 minutter.

Vi vil kun innhente og registrere opplysninger om deg som kommer frem av spørreskjema som du besvarer og resultat fra tester beskrevet over, samt alder, høyde og vekt.

MULIGE FORDELER OG ULEMPER

Fordelen for deg å delta er at du får en undersøkelse av både hørsel, funksjon til balanseorganet og balanse. Du får muligheten å spørre om både hørselstap og balanse og vi hjelper deg med råd samt kan formidle nyttige kontakter til Fysioterapeut og tilbudet «Sterk og Stødig» https://sterkogstodig.no/no/startside/ som kan være deg til hjelp. Det er ingen ulemper utover at vi bruker litt av din tid.

FRIVILLIG DELTAKELSE OG MULIGHET FOR Å TREKKE DITT SAMTYKKE

Det er frivillig å delta i prosjektet. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg. Dersom du trekker tilbake samtykket, vil det ikke forskes videre på dine helseopplysninger. Du kan også kreve at dine helseopplysninger i prosjektet slettes eller utleveres innen 30 dager. Adgangen til å kreve destruksjon, sletting eller utlevering gjelder ikke dersom materialet eller opplysningene er anonymisert. Denne adgangen kan også begrenses dersom opplysningene er inngått i utførte analyser, eller materialet er publisert.

23.04.2022

Dersom du senere ønsker å trekke deg eller har spørsmål til prosjektet, kan du kontakte prosjektleder (se kontaktinformasjon på siste side).

HVA SKJER MED OPPLYSNINGENE OM DEG?

Opplysningene som registreres om deg skal kun brukes slik som beskrevet under formålet med prosjektet, og planlegges brukt til 2023. Eventuelle utvidelser i bruk og oppbevaringstid kan kun skje etter godkjenning fra REK og andre relevante myndigheter. Du har rett til innsyn i hvilke opplysninger som er registrert om deg og rett til å få korrigert eventuelle feil i de opplysningene som er registrert. Du har også rett til å få innsyn i sikkerhetstiltakene ved behandling av opplysningene. Du kan klage på behandlingen av dine opplysninger til Datatilsynet og institusjonen sitt personvernombud.

Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger (=kodede opplysninger). En kode knytter deg til dine opplysninger gjennom en navneliste. Det er kun prosjektleder som har tilgang til denne listen. Kodenøkkelen vil etter endt prosjekt 2023 slettes.

Anonyme opplysninger om deg vil bli oppbevart i fem år etter prosjektslutt av kontrollhensyn.

DELING AV OPPLYSNINGER

Dersom du samtykker at kodede opplysninger fra balansetest lagres hos Høresentralen krysser du her: ☐

GODKJENNINGER

Regional komité for medisinsk og helsefaglig forskningsetikk har gjort en forskningsetisk vurdering og godkjent prosjektet (REK : 478016).

NTNU og Høresentralen ved St. Olavs hospital og prosjektleder Professor Ann-Katrin Stensdotter er ansvarlig for personvernet i prosjektet.

Vi behandler opplysningene basert på ditt samtykke.

KONTAKTOPPLYSNINGER

Dersom du har spørsmål til prosjektet eller ønsker å trekke deg fra deltakelse, kan du kontakte Professor **Ann-Katrin Stensdotter** ved NTNU: e-post ann-katrin.stensdotter@ntnu.no, telefon 73559277, eller Professor og overlege **Kenneth Ervik** Høresentralen, St. Olavs hospital: e-post Kenneth.Ervik@stolav.no, telefon 72576836.

Dersom du har spørsmål om personvernet i prosjektet, kan du kontakte personvernombudet ved institusjonen: thomas.helgesen@ntnu.no.

Datatilsynets e-postadresse er: postkasse@datatilsynet.no

23.04.2022

JEG SAMTYKKER TIL Å DELTA I PROSJEKTET OG TIL AT MINE PERSONOPPLYSNINGER BRUKES SLIK DET ER BESKREVET

Sted og dato	Deltakers signatur
	Deltakers navn med trykte bokstaver

Appendix 3. An informed consent document for the control group.

23.04.2022

NTNU
Faculty of Medicine and Health Sciences

ST. OLAVS HOSPITAL
UNIVERSITETSSYKEHUSET I TRONDHEIM

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FORMÅLET MED PROSJEKTET OG HVORFOR DU BLIR SPURT

Dette er et spørsmål til deg om å delta i et forskningsprosjekt som ung frisk kontrollperson uten hørselstap. Studien handler om hvorvidt og hvordan hørselstap påvirker hverdagen med tanke på mobilitet og balanse. Dette prosjektet er derfor et samarbeid mellom utdanningene for fysioterapi, audiologi, og bevegelsesvitenskap ved NTNU samt Høresentralen ved St. Olavs hospital. Vi spør deg som student derfor vi trenger i tillegg til en frisk eldre kontrollgruppe også en frisk ung kontrollgruppe, da også eldre uten hørselstap vil ha for alderen normalt nedsatt hørsel og nedsatt balanseevne sammenlignet med unge mennesker.

HVA INNEBÆRER PROSJEKTET FOR DEG?

Som frisk kontrollperson trenger vi likevel bekrefte at du har normal hørsel. Du vil derfor gjennomgå en automatisert hørselstest. Du vil også gjennomgå ulike balansetest i bevegelseslabben ved NTNU. Det ene testet innebærer å gå innendørs i ett minutt, det andre kalles Romberg der du står i ro i 60 sekunder. Romberg testes med øyene åpne, lukket og stående på et mykt underlag, samt med ulike lyd i rommet og via hodetelefon. Vi vil også teste din balanse med simulerthørselstap der vi bruker ørepluggar. Et rekkverk finnes for balansestøtte. For din sikkerhet vil det alltid være to personer til stede i labbet. Dette testet tar ca 30 minutter.

Vi vil kun innhente og registrere opplysninger om deg som kommer frem av resultat fra tester beskrevet over, samt alder, høyde og vekt.

MULIGE FORDELER OG ULEMPER

Fordelen for deg å delta er at du får en undersøkelse av hørsel og en innsikt i hvordan forskning skjer i bevegelseslabb. Det er ingen ulemper utover at vi bruker litt av din tid.

FRIVILLIG DELTAKELSE OG MULIGHET FOR Å TREKKE DITT SAMTYKKE

Det er frivillig å delta i prosjektet. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg. Dersom du trekker tilbake samtykket, vil det ikke forskes videre på dine helseopplysninger. Du kan også kreve at dine helseopplysninger i prosjektet slettes eller utleveres innen 30 dager. Adgangen til å kreve destruksjon, sletting eller utlevering gjelder ikke dersom materialet eller opplysningene er anonymisert. Denne adgangen kan også begrenses dersom opplysningene er inngått i utførte analyser, eller materialet er publisert.

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HVA SKJER MED OPPLYSNINGENE OM DEG?

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23.04.2022

REK og andre relevante myndigheter. Du har rett til innsyn i hvilke opplysninger som er registrert om deg og rett til å få korrigert eventuelle feil i de opplysningene som er registrert. Du har også rett til å få innsyn i sikkerhetstiltakene ved behandling av opplysningene. Du kan klage på behandlingen av dine opplysninger til Datatilsynet og institusjonen sitt personvernombud.

Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger (=kodede opplysninger). En kode knytter deg til dine opplysninger gjennom en navneliste. Det er kun prosjektansvarlig som har tilgang til denne listen. Kodenøkkelen blir slettet etter avsluttet prosjekt 2023.

Anonyme opplysninger om deg vil bli oppbevart i fem år etter prosjektslutt av kontrollhensyn.

DELING AV OPPLYSNINGER

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KONTAKTOPPLYSNINGER

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23.04.2022

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Sted og dato

Deltakers signatur

Deltakers navn med trykte bokstaver

NTNU

Norwegian University of
Science and Technology