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Effect of hearing aids on static balance function in elderly with hearing loss

Hossein Negahban[a,b], Mahtab Bavarsad Cheshmeh ali[c,*], Gholamhossein Nassadj[c]

[a] Department of Physical Therapy, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, Iran
[b] Orthopedic Research Center, Mashhad University of Medical Sciences, Mashhad, Iran
[c] Musculoskeletal Rehabilitation Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

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ABSTRACT

While a few studies have investigated the relationship between hearing acuity and postural control, little is known about the effect of hearing aids on postural stability in elderly with hearing loss. The aim was to compare static balance function between elderly with hearing loss who used hearing aids and those who did not use. The subjects asked to stand with (A) open eyes on rigid surface (force platform), (B) closed eyes on rigid surface, (C) open eyes on a foam pad, and (D) closed eyes on a foam pad. Subjects in the aided group (n = 22) were tested with their hearing aids turned on and hearing aids turned off in each experimental condition. Subjects in the unaided group (n = 25) were tested under the same experimental conditions as the aided group. Indicators for postural stability were center of pressure (COP) parameters including; mean velocity, standard deviation (SD) velocity in anteroposterior (AP) and mediolateral (ML) directions, and sway area (95% confidence ellipse). The results showed that within open eyes–foam surface condition, there was greater SD velocity in the off-aided than the on-aided and the unaided than the on-aided ($p < 0.0001$ for SD velocity in AP and ML). Also, no significant differences were found between the off-aided and unaided group ($p = 0.56$ and $p = 0.77$ for SD velocity in AP and ML, respectively). Hearing aids improve static balance function by reducing the SD velocity. Clinical implications may include improving hearing inputs in order to increase postural stability in older adults with hearing loss.

1. Introduction

After the arthritis and hypertension, the hearing loss is the most common chronic condition in elderly population [1,2], so that approximately 90% of the elderly people over 80 years of age are affected by hearing loss [2].

Sensory information from visual, vestibular, and somatosensory inputs is the major sensory inputs to maintain postural stability [3–5]. Some researchers suppose that the audition provides spatial acoustic cues that may be considered as important sensory information to maintain postural control [4–10]. Based on this hypothesis, a limited number of studies have examined the relationship between hearing acuity and postural stability, mostly reported a significant, strong relationship [1,5,11].

Hearing and vestibular organs are closely related both anatomically and physiologically. They have similar mechanoreceptors which detect sound, head orientation and movement in space [5,12]. It is assumed that hearing loss is associated with loss of labyrinthine function and may contribute to postural instability [13,14]. Therefore, one may speculate that hearing aids not only improve the auditory information, but might serve as an instrument to enhance postural stability in elderly population with hearing loss [4,10]. To date, two studies have examined the effect of hearing aids on postural stability in elderly with hearing loss [4,10]. The method used in the current study is different from the Rumalla's work in which they looked at time until falling by Romberg test, whereas the current study looked at center of pressure (COP) measures. Evaluating postural stability using force platform enables us to evaluate the impact of visual and somatosensory deprivations on static balance function (COP measures) under different conditions of open/closed eyes and rigid/foam surfaces. Also, our study is an extension of Vitkovic's work in which their subjects were tested with hearing aids turned on whereas, in our study, subjects in the aided group were tested with their hearing aids turned on (on-aided condition) and hearing aids turned off (off-aided condition) that may provide a significant benefit to the field. We assessed the aided group twice because we wanted to know if hearing aid use can improve postural control over time even if it is not turned on. Moreover, while Vitkovic et al. used the total path length to quantify postural sway, we calculated a variety of COP measures (including velocity and sway area parameters) to evaluate different aspects of postural behavior. Therefore,

* Corresponding author.
E-mail addresses: honegahban@yahoo.com (H. Negahban), mah.bavarsad@gmail.com (M. Bavarsad Cheshmeh ali), nassadj@yahoo.com (G. Nassadj).

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the objective of this study was to compare static balance function between elderly with hearing loss who used hearing aids (under two conditions of on-aided and off-aided) and those who did not use.

2. Material and methods

2.1. Participants

This study was carried out with the approval of the Review Board of Ahvaz Jundishapur University of Medical Sciences (AJUMS), Ahvaz, Iran. All subjects signed informed consent form before participation in the study.

Eligible subjects (n = 47) were recruited from the outpatient clinics of audiology located at Ahvaz, Iran. Inclusion criteria were elderly adults aged over 60 years old who had bilateral hearing loss; had hearing threshold between 40 and 70 dB; wore bilateral hearing aids for 3 month or more (for the aided group; n = 22: 16 male and 6 female); and could ambulate without assistive devices. A total of 25 participants (18 male and 7 female) were recruited for the unaided group. Subjects were excluded if they had hearing disorders caused by otosclerosis or middle ear infections; a history of neurological diseases; surgical operation on the lower limbs or spine in the past 6 months; and pain in lower limb during standing (e.g. knee pain, low back pain).

The hearing threshold of aided (with their hearing aids turned off) and unaided participants was determined using air conduction audiometry. For these subjects, the average of air conduction threshold at 4 frequencies (i.e. 0.5, 1, 2 and 4 kHz) was between 40 and 70 dB (i.e. moderate hearing impairment to relatively severe hearing impairment). Also, the hearing threshold of aided participants (with their hearing aids turned on) was achieved by free field audiometry. For these subjects, the average of air conduction threshold at 4 frequencies (i.e. 0.5, 1, 2 and 4 kHz) was between 20 and 35 dB (i.e. normal hearing to approximately mild hearing impairment).

2.2. Procedure

Static balance function was objectively assessed using a strain gauge Bertec 4060-10 force platform and Bertec AM-6701 amplifier (Bertec Corporation, Columbus, Ohio, USA). Indicators for postural stability were COP parameters including: mean velocity, standard deviation (SD) velocity (in anteroposterior (AP) and mediolateral (ML) directions), and sway area (95% confidence ellipse). The rationale for choosing mean velocity and SD velocity was their acceptable reliability reported in previous studies [15,16]. Also, sway area was chosen to increase the comparability of our study with previous studies [11].

The subjects were asked to stand with (A) open eyes on rigid surface (force platform), (B) closed eyes on rigid surface, (C) open eyes on a foam pad, and (D) closed eyes on a foam pad. In all conditions, subjects were instructed to stand as still as possible with their feet together and their arms hanged at their sides. In the closed eyes conditions, subjects wore a blindfold. In the foam conditions, subjects were instructed to stand on a foam pad (40 × 60 cm dimensions, 10 cm thickness, and 35 kg/m^3 density) placed on the force platform. Each condition was repeated in 3 trials lasting for 30 s (each trial). The presentation of all postural conditions (A, B, C, D) was counterbalanced for each subject to minimize learning effects. However, the three trials of each postural condition were completed sequentially. Also, subjects in the aided group were tested first with their hearing aids turned on, and then with their hearing aids turned off. Moreover, a rest time of five minutes was considered between postural conditions to minimize fatigue. The participants were asked to sit on a chair during the rest period.

Subjects in the aided group were tested under two status of on-aided and off-aided in each experimental condition. Subjects in the unaided group were tested under the same experimental conditions as the aided group. However, the aided group was assessed twice, whereas the unaided group was only assessed once. The experiment was performed in a regular room with ambient sound.

2.3. Statistical analysis

The subjects' mean score on 3 trials was considered as the final score. Mean values of the COP parameters of the aided group were compared with those of the unaided group using a 2-way mixed model analysis of variance [17], with group (i.e. on-aided, off-aided, unaided groups) as between-group factor and postural conditions (i.e. open eyes–rigid surface, closed eyes–rigid surface, open eyes–foam surface, closed eyes–foam surface) as within-group factor. A difference was considered to be statistically significant at $p < 0.05$. For multiple comparisons, the Bonferroni adjustment method was used [17]. We also calculated a 95% confidence interval (CI) for the main results of this study.

3. Results

There were no statistical differences between the 2 groups with regards to age (67.4 ± 3.5 vs. 67.1 ± 5.5 yr, $p = 0.82$), height (168.9 ± 8.5 vs. 167.0 ± 8.99 cm, $p = 0.45$), and BMI (25.8 ± 3.0 vs. 25.2 ± 2.9 kg/m^2, $p = 0.48$). The mean time of hearing aids acquisition (i.e. the length of time the subjects have worn hearing aids) in the aided group was 33.5 ± 16.68 month (mean ± SD). The mean hearing threshold for the unaided and aided participants with their hearing aids turned off and their hearing aids turned on was 46.32 ± 8.52, 45.40 ± 4.36, and 23.39 ± 4.82 dB, respectively.

The results of variance analysis (Table 2) showed that the interaction of group by postural conditions was significant for SD velocity in AP ($F_{2,139} = 5.06$, $P = 0.001$) and ML ($F_{2,166} = 8.34$, $P < 0.0001$) directions. Therefore, the simple main effects of group within each experimental condition were analyzed by one-way ANOVA. The results of multiple comparisons showed that within open eyes-foam surface condition, there was greater SD velocity in the off-aided than the on-aided ($p < 0.0001$, 95% CI = −12.73–−4.39 for SD velocity in AP and $p < 0.0001$, 95% CI = −14.23–−7.61 for SD velocity in ML) and the unaided than the on-aided ($p < 0.0001$, 95% CI = 6.25 to 14.34 for SD velocity in AP and $p < 0.0001$, 95% CI = 8.62–15.04 for SD velocity in ML) (Table 1). Also, no significant differences were found between the off-aided and unaided group ($p = 0.56$, 95% CI = −2.30 to 5.77 for SD velocity in AP and $p = 0.77$, 95% CI = −2.29 to 4.12 for SD velocity in ML) (see Fig. 1).

In the current study, significant differences between groups were observed for SD velocity within open eyes-foam surface condition. Therefore, the relationship (correlation) between the time of acquisition of hearing aids and benefit of hearing aids (i.e. difference between off-aided and on-aided conditions) on postural control was analyzed using Pearson correlation coefficient for the SD velocity in both AP and ML directions. The results revealed a significant positive correlation for SD velocity in AP ($r = 0.50$, $p = 0.017$), but not in ML ($r = 0.31$, $p = 0.15$) direction (Fig. 2).

4. Discussion

The results showed that the auditory information are important in maintaining static balance function as wearing and turning-on the hearing aids provided a significant improvement in postural stability (as indicated by decreased SD velocity) among older adults with hearing loss. Therefore, using hearing aids in the elderly could be considered as a novel treatment modality for postural instability observed in elderly with hearing loss [4,10].

It is necessary to mention that the hearing conditions have not been counter balanced in the current study (i.e. on-aided was always recorded first followed by off-aided). Therefore, as the observed changes could be in part due to fatigue or other factors not related to hearing aids, the results of differences between two conditions of on- and off-