Table 1. Study Designs, Outcome Measures, and Results of Research Studies Investigating Hearing and Postural Stability in Older Adults

Study	**Participants**	**Testing Conditions**	**Outcome Measures**	**Results/Implications**
Rumalla et al[1] **(2015)** Cross-sectional study *Aim*: To compare static balance performance of older adults with bilat. HA use under aided (HA on) and unaided (HA off) conditions	N=14 older adults (65-91yo) with bilat. hearing loss - *exclusion:* vertigo or imbalance, ortho/neuro conditions affecting balance, use of assistive device - 7 female, 12.75dB mean audiometric gain	*Balance:* participants attempt to complete each balance test for 30s without moving their arms or feet, opening their eyes, or taking steps - 3 trials of each condition and median scores taken as final measurements *Stance conditions: (4)*— 1) Romberg on foam + HA on, 2) Romberg on foam + HA off, 3) Tandem stance + HA on, 4) Tandem stance + HA off *Sound conditions:* broadband white noise administered from a speaker *Visual conditions:* blindfolded	*Postural stability*: - Romberg test, -Tandem stance *Balance confidence*: - Activities Specific Balance Confidence (ABC) scale - Subjective perception of difference *Statistical analysis:* two-tailed nonparametric, Wilcoxon sign-ranked test	Statistical difference in aided versus unaided in Romberg on foam test (P= 0.0051). Statistical difference in aided versus unaided in Tandem stance test (P= 0.0052). Mean score for the Tandem Stance test without HA (unaided) was 4.5 ± 3.3s, with a median value of 3.2s. Mean score for the Tandem Stance test with HA (aided) was 9.8 ± 7.7.4s, with a median of 9.6s. Correlation between mean improvement on Romberg (in the 10 participants) and gain with hearing aid use was not detectable, (Spearman's rho of − 0.115, P= 0.751). Correlation between mean improvement on Tandem stance and gain with hearing aid use was not detectable, (Spearman's rho of 0.400, P= 0.600). **Implications**: HA use may improve balance in OA with bilateral hearing loss **Limitations**: small sample size, ceiling effect (Romberg), excluded ABC quantitative results, and useful participant characteristics (length of HA use, comorbidities, etc.)
Negahban et al[2] **(2017)** Cross-sectional study *Aim*: To compare static balance performance b/t elderly with HL with HA (on and off) and elderly with HL without HA	N=47 older adults (>60yo) - *Exclusion:* audiologic disorders, LE/spine surgeries in past 6mo, LE pain with standing - *Aided group:* 67.4 ± 3.5 yo; 33.5 ± 16.68 mo of HA use; hearing threshold without HA 45.4± 4.36dB; hearing threshold with HA 23.39 ± 4.82 dB - *Unaided group:* 67.1 ± 5.5 yo; hearing threshold 46.32 ± 8.52 dB (no HA)	*Balance:* participants attempt to complete each standing balance condition for a max 30s using force platform posturography to objectively quantify balance. - 3 trials of each condition with 5-minute rest breaks in between each condition. Aided group assessed twice—with HA on and with HA off *Stance conditions:* Romberg with 1) EO + rigid surface 2) EC + rigid surface 3) EO + foam, 4) EC + foam *Sound conditions:* ambient sound *Visual conditions:* blindfolded for EC conditions.	*Postural stability*: Force platform posturography - COP parameters: mean velocity, anteroposterior (AP) standard deviation velocity, mediolateral (ML) standard deviation velocity, and sway area. *Statistical analysis:* 2-way mixed model analysis of variance (group as between-group factor, postural conditions as within-group factor); Boinferroni adjustment method for multiple comparisons	Statistical differences in group interactions (postural conditions) in SD velocity for both AP and ML directions. AP and ML SD velocity significantly greater off-aided vs. on-aided (p<0.0001) and un-aided vs. on-aided (p <0.001). No statistical difference in SD velocity for off-aided v unaided (p=0.56 for AP and p=0.77 for ML) in EO+foam. Significant positive correlation (r= 0.50, p= 0.017) b/t time of HA acquisition and difference b/t aided and unaided conditions for AP SD velocity. No significant correlation–ML SD velocity r=0.31, p=0.15 No significant differences—mean velocity (F=0.84, p=0.507) or sway area (F=1.48, p=0.203). No statistically significant differences in regard to age, BMI, or height between groups. **Implications:** HA use improves postural stability when on and functioning in OA with hearing loss evidenced by reduced SD velocity **Limitations**: No counterbalance, fatigue/learning effects from repeated testing, excludes useful participant characteristics (falls history, comorbidity, etc.)

Study	**Participants**	**Testing Conditions**	**Outcome Measures**	**Results/Implications**
McDaniel et al[3] **(2018)** Cross-sectional study *Aim*: To examine effect of bilateral hearing aid use on postural stability in older adults	N=22 adults (58-81yo) bilat. HA users - *Exclusion*: neuro disorders, stroke, stenosis, LE joint replacements, balance-altering medications - 68.5yo on avg, 19 males, avg 3.5 years of HA use, 7 fell in past year, 5 report balance concerns	*Balance:* participants complete the SOT testing twice in one day with HA on + HA off, with 5 min break *Stance conditions:* 6 test conditions of the SOT–1) quiet stance + EO 2) quiet stance + EC 3) quiet stance + EO + box moves with participant as they sway; conditions 4-6 repeated with force plate unlocked to allow movement with sway of the participant; feet shoulder width apart *Sound condition*: "multitalker babble" at 65dB	*Postural stability:* Sensory Organization Testing (SOT)—results range from 0 to 100, with 100 being perfect stability. - Participant is marked for "fall" if takes a step to regain stability during the trial *Statistical analysis*—paired *t* test for aided and unaided conditions (SOT composite) and repeated measures analysis for each 6 conditions	No significant difference in aided v. unaided for SOT composite score → $t(21) = -1.6$, $p = .0124$. "No significant differences between or among variables" in aided v. unaided for the 6 conditions → $F(5) = 1.431$, $p = 0.218$. **Implications:** HA did not improve balance performance in OA who use them when using SOT. **Limitations:** small sample size, ceiling effects of SOT, insufficient power, gender imbalance (19/22 were male), different sound source than similar studies
Vitkovic et al[4] **(2017)** Cross-sectional study *Aim*: To investigate the effects of auditory input on postural sway and examine the use of hearing map to control balance	Total N= 97 (21-83yo) - 3 groups— normal hearing (N=50), hearing loss (N=28), vestib. dysfunction (N=19) - *exclusion:* balance-limiting ortho/neuro conditions, use of AD to maintain static stance - NH= 21-56yo, 10 males, - HL= 26-80yo, 13 males - VD= 34-83yo, 10 males	*Balance conditions*: feet apart (10cm) for 60s *Stance conditions (4):* 1) firm surface + EO 2) firm surface + EC 3) foam + EO and 4) foam + EC *Sound conditions (4):* 1) ambient 2) ear plugs + sound 3) continuous white noise 4) moving noise HI group tested twice with and without HA *Visual condition:* EC when indicated	*Postural stability*: force platform posturography via Nintendo Wii Balance Board (WBB) - COP parameter: total path length *Statistical Analysis*: 2-factor repeated measures ANOVA - Measured effect of hearing loss on balance within the HI group instead of comparing HI to normal group due to confounding age differences	*Normal group*—"significant effect of sound environment ($p=0.018$) and standing position ($p<0.001$), but no significant interactions ($p> 0.05$)"; larger COP path lengths with EC+ foam, and in the *absence* of sound (significant $p= 0.025$). *HI group*—no significant difference in balance in sound environment (but slight increase in sway without HA, decrease with HA when sound provided). **Implications:** NH utilize sound to reduce postural sway, HA may improve postural sway in the presence of sound for HL, auditory input is more utilized among VD **Limitations:** not exclusive to OA, variety of sound sources reduces generalizability to similar studies
Stevens et al[5] **(2016)** Cross-sectional study *Aim*: To examine effect of hearing impairment on ability to regain balance	Total N=18 (9-78yo) - *exclusion:* none listed - 47 ± 20yo; 10 females; hearing > 30 dB HL bilat.; 6 report balance concerns; *comorbidities:* 2 unilat. vestibular loss, 1 Pendred's syndrome, 1 history of gentamicin toxicity; 1 BPPV	*Balance conditions*: maintain stance on balance platform for 3, 20s blocks for each condition—combinations of the conditions below *Stance condition:* feet apart on stable + unstable surfaces *Sound conditions*: earth-fixed and head-fixed sound sources; sound v. no sound *Visual conditions*: EC (blind folded) and EO (landscape image)	*Postural stability*: Force platform posturography - COP Parameters: root mean square of velocity *Statistical analysis:* Pearson's product moment, two-tailed paired *t*-test	Sway ranged from 0.9 to 7.0cm/s with EC+ no sound. Sway ranged from 1.0 to 4.7cm/s with EC + sound. Almost linear relationship between sway in sound v. no sound with EC—0.59 slope, sound decreased sway less than 2/3 of sway without sound. Both NH and HL decreased postural sway with sound. **Implications:** presence of sound reduces sway. **Limitations:** doesn't report exclusion criteria, included multiple comorbidities, small sample size, not exclusive to older adults, statistical significance is unclear.

Study	Participants	Testing Conditions	Outcome Measures	Results/Implications
Viljanen et al[6] (2009) Prospective Cohort *Aim*: To explore if hearing impairments predict falls and to investigate the association of postural stability with falls incidence	Total N= 434 (63-76yo) 103 monozygotic + 114 dizygotic female twin pairs - *exclusion:* osteosclerosis, absent postural sway results, no participation in fall follow-up - 2% use HA, 19% fell in past 12mo, 21dB mean hearing acuity	*Balance conditions*: semi-tandem stance for 20s *Stance condition:* "stocking feet," hands at sides *Sound condition:* not indicated *Visual conditions*: fixed, eye-level spot 2m in front	*Postural stability*: Force platform posturography - COP Parameters: mean ML and AP sway velocity and velocity moment *Falls assessment:* - at least 1 fall, at least 2 falls, or at least 1 injurious fall *Statistical analysis*: negative binomial regression model	Increased COP displacement and velocity in hearing impaired group. COP mean velocity moment increased with each quartile group (40.7, 46.3, 50.6, and 52.8mm/s^2 for the best, second, third, and worst quartile, respectively). Falls rate increased with severity of hearing impairment—7.1, 6.7, 10.4, and 11.3 falls per 100 persons each month for best, second, third, and worst quartile, respectively. 30% of poorest quartile compared to 17% of best quartile had 2 or more falls (p=0.42). **Implications:** Women with HL at higher risk of falls and demonstrate increased postural sway; severity of hearing impairment associated with increased risk of falls and recurrent falls **Limitations:** study type (not randomized or controlled), limited to female gender, 20s trials reduce generalizability compared to other studies, doesn't indicate sound conditions

Key: AD=assistive device; AP=anteroposterior; bilat.= bilateral; b/t= between; BPPV= Benign paroxysmal positional vertigo; COP= center of pressure; dB= decibel; EC=eyes closed; EO=eyes open HA=hearing aid; HI= hearing impaired; HL=hearing loss; LE= lower extremity; m=meter; mo=months; ML=mediolateral; NH= normal hearing; OA= older adults; s=seconds; SD= standard deviation; SOT=sensory organization test; unilat.=unilateral; vestib.=vestibular; VD=vestibular dysfunction; yo= years old

References:

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