

The relationship between hearing aid use and falls in older adults with sensorineural hearing loss

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Overview

- ▶ Background of fall significance and review literature on hearing aid use and fall risk
- ▶ Aims and study design/methods
- ▶ Results: differences in fall prevalence and fall-risk by hearing aid use
- ▶ Discussion: Conclusions, limitations, future research

Fall statistics

- ▶ Every second of every day, an older adult falls
 - ▶ 1 in 4 over the age of 65 fall each year
- ▶ Falls are the number one cause of TBIs and hospitalization in the elderly
- ▶ Falls are more costly to the healthcare system than smoking or obesity (\$50 billion annually)

TAKE ACTION TO Prevent Falls and Reduce Healthcare Spending

Older adult falls cost
the U.S. healthcare system

\$50 Billion

every year.



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Centers for Disease
Control and Prevention
National Center for Injury
Prevention and Control

Intrinsic

Systems

Socio
demographic

Diseases

Medications

Risk
Factors
for Falls

Extrinsic

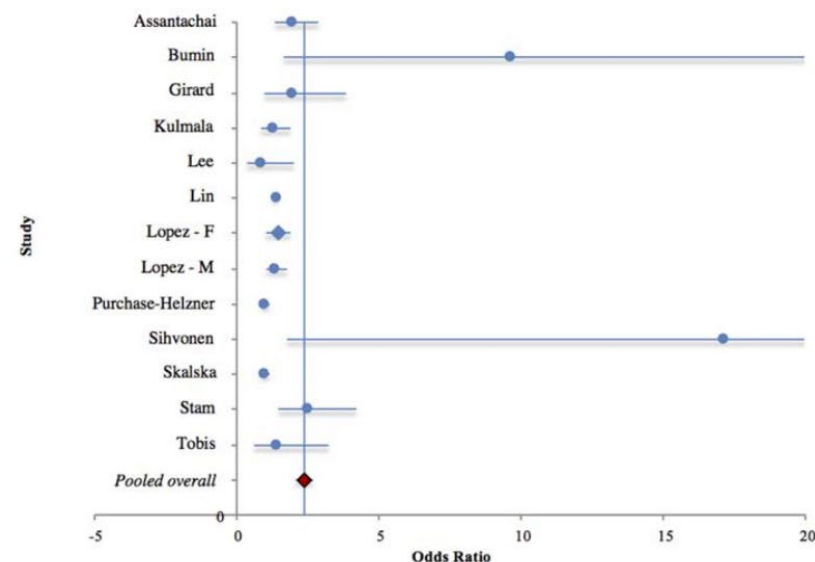
Environmental

Adapted from Ambrose, Paul, and Hausdorff (2013)
and S. R. Lord, Menz, and Sherrington (2004).

Hearing loss as a risk factor for falls

- ▶ Lin & Ferrucci (2012) found a dose-response relationship that for every 10 dB of hearing loss, risk of falling increased 1.4-fold.
- ▶ Meta-analysis by Jiam et al (2016) found older adults with hearing loss had 2.4 times the risk of falls than those without hearing loss.

Study Source	Sample Size	Odds Ratio (95% CI)
Assantachai	1043	1.97 (1.35-2.86)
Bumin	33	9.64 (1.63-56.9)
Girard	298	1.97 (1.001-3.88)
Kulmala	428	1.3 (0.89-1.92)
Lee	173	0.88 (0.38-2.04)
Lin	2017	1.4 (1.3-1.5)
Lopez - F	3014	1.45 (1.08-1.93)
Lopez - M	2340	1.38 (1.08-1.78)
Purchase-Helzner	9704	1 (0.88-1.15)
Sihvonen	79	17.14 (1.78-165.6)
Skalska	4920	1 (0.88-1.5)
Stam	1865	2.5 (1.49-4.19)
Tobis	47	1.42 (0.62-3.26)

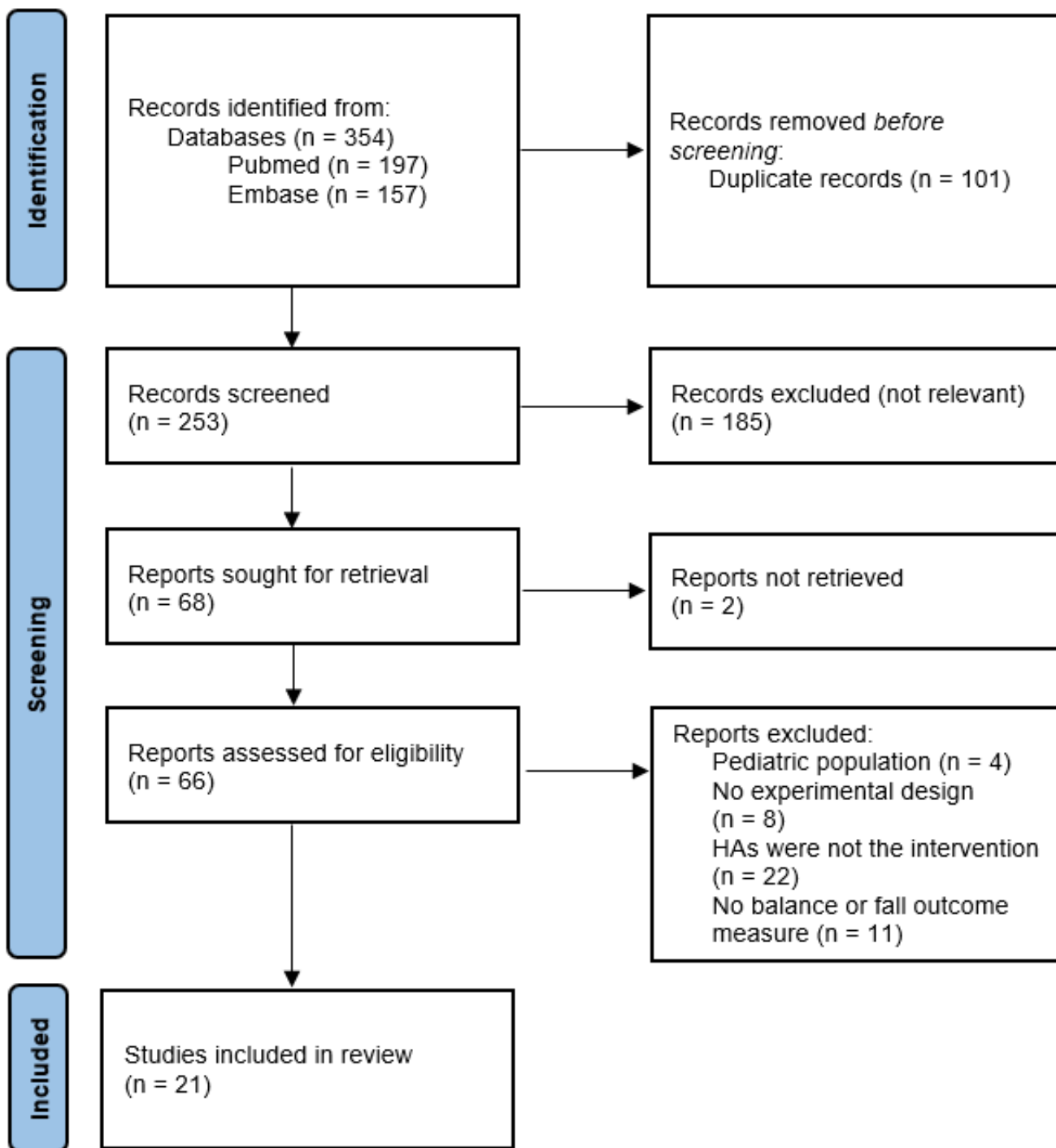


Proposed Mechanisms

- ▶ Concomitant medical factors that degrade both the auditory and vestibular systems
- ▶ Increased cognitive load of communication reducing overall executive function capacity to maintain balance/avoid falls
- ▶ Loss of auditory cues necessary for accurate spatial orientation

Research Question

- ▶ 2 of the 3 theories are directly addressed/corrected by hearing aids (reduction in cognitive load, improved access to auditory spatial landmarks).
- ▶ Does use of hearing aids reduce the likelihood of a fall?



Systematic Literature Review

Literature Review

- ▶ 21 studies included, can be separated based on outcome measure assessed
 - ▶ Measures of postural sway/stability
 - ▶ Measures of gait
 - ▶ Falls

Postural Sway/Stability

- ▶ 7 studies have assessed postural sway with HI individuals aided and unaided
 - ▶ 5 have found significantly better performance when aided
 - ▶ 1 found only HI individuals with vestibular dysfunction performed better aided
 - ▶ 1 found no significant difference

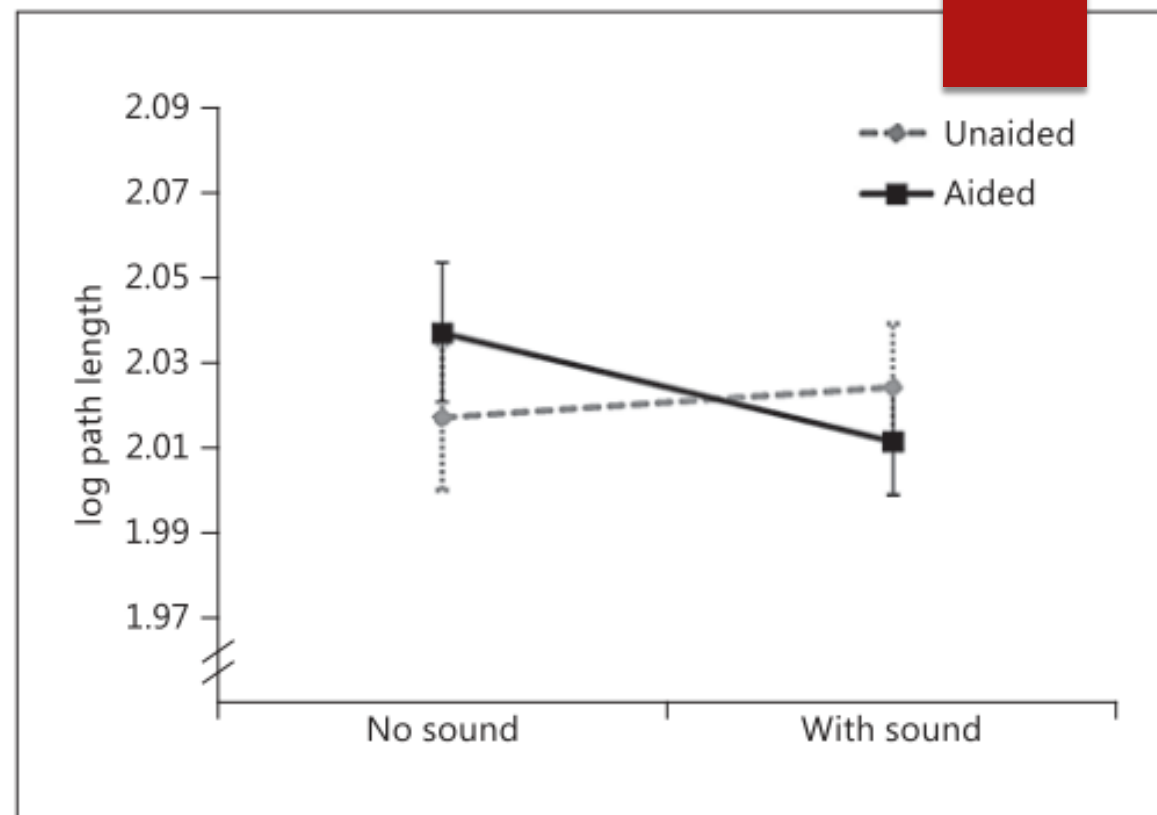


Fig. 4. The effect of sound environment in aided and unaided conditions on the mean log path length in 19 hearing aid users. Data points represent the mean log path length for all 4 standing conditions in that sound environment and aided condition. Error bars are displayed as ± 2 standard residual errors. There was no significant effect of sound environment or aided condition ($p > 0.05$), but there was a significant interaction ($p = 0.048$).

Gait

- ▶ Only 3 studies looked at gait velocity, stride length, TUG or steps to regain balance
 - ▶ One was a case series which showed better performance with device on than off
 - ▶ One did not find any aided vs unaided differences
 - ▶ One found unaided individuals had to take more steps to regain balance

Hearing aid use and falls

- ▶ Systematic literature review found 9 studies that directly evaluated the association between hearing aid use and fall risk
 - ▶ 4 found that hearing aid users had significantly higher odds of experiencing a fall
 - ▶ 3 did not find significance in the relationship
 - ▶ 2 found hearing aid users had significantly lower odds of experiencing a fall

Studies finding hearing aids increase odds of falling



Study	Study design	Participants	Outcome measure	Conclusion
Sprince et al. (2003)	Case/control cross-sectional survey	6,999 Iowa farmers (mean age 50.1)	Self-reported fall-related farm injury in past 12 months	Difficulty hearing normal conversation (even if wearing a hearing aid) related to fall risk OR 1.82 (95% CI: 1.07-3.08)
Chu et al. (2004)	Case/control cross-sectional survey	448 cases who experienced a proximal humerus fracture and 2,023 controls (age range 45-85+)	Incident proximal humerus fractures over age 45 between 1996-2001	Fall-related risk factor: hearing aid used almost always OR 1.82 (95% CI: 1.08-3.08)
Gopinath et al. (2016)	5-year longitudinal cohort study	1,478 Australians over the age of 55	Self-reported incident falls in the 12 months prior to study visits	Those who reported hearing aid use had higher odds of falling OR 1.76 (95% CI: 1.1-2.84)
Crifer and Gustavson (2020)	Case/control cross-sectional survey	28 community dwelling older adults (mean age 70.6), 28 audiology clinic patients without hearing aids (mean age 71.5), 18 audiology clinic patients with hearing aids (mean age 72.9)	Self-reported falls in the past 12 months and unaided HHIE scores	Audiology patients with HAs reported more falls ($p=0.003$) than either of the other 2 groups.

Studies finding no significant relationship



Study	Study design	Participants	Outcome measure	Conclusion
Kamil et al. (2016)	11-year longitudinal cohort study	2,000 total participants between 70-79, 407 with HL (137 HA users, 270 non-users).	Self-reported falls in the past 12 months	For those with moderate or greater HL, rates of experiencing a fall did not differ between HA users and non-users (p=0.22)
Powell et al. (2021)	Pooled cross-sectional analysis of 20-year national survey	152,872 (8391 HA users) individuals aged 50+ who completed the National Health Interview Survey between 1997-2017	Self-reported falls in the past 3 months, falls due to dizziness in the past 3 months	Hearing aid use did not affect odds of experiencing a fall OR 1.01 (95% CI: 0.55-1.86) or odds of experiencing a fall due to dizziness OR 1.55 (95% CI: 0.82-2.93)
Riska, Peskoe, Kuchibhatla, et al. (2021)	Pooled cross-sectional analysis of 5-year national survey	8,091 individuals age 40+ who completed the National Health and Nutrition Examination Survey (NHANES)	Self-reported falls in the past 12 months	Greater severities of hearing loss was correlated with increased fall risk but hearing aid use did not modify this relationship (p=0.72)

Studies finding hearing aids reduce odds of falling

Study	Study design	Participants	Outcome measure	Conclusion
Mahmoudi et al. (2019)	8-year longitudinal retrospective cohort study of health insurance claims data	114,862 participants with HL (mean age 79.8) 14,109 HA users and 100,753 non-users)	Incident injurious falls by ICD code	HA users had lower risk of injurious fall than non-users (HR= 0.87; 95% CI: 0.80-0.93)
Tiase et al. (2020)	1-year retrospective case/control study	6,668 inpatients 18+ with hearing loss (1,736 HA users, 4,932 non-users)	Fall occurring during hospitalization	Patients who reported HL were more likely to experience a fall OR 1.74 (95% CI: 1.46-2.07) Patients without HA usage had even higher risk of falls OR 2.7 (95% CI: 1.64-4.69) HA users were not more likely than normal hearing controls to experience a fall (p=0.889)

Gaps in the Literature

- ▶ Using measures of postural stability, gait or fractures as a proxy for falls
- ▶ Focus on hearing loss/falls association—HA use was secondary analysis and underpowered
- ▶ None collected data about frequency and duration of hearing aid use (2 stratified never, half the time, always)
- ▶ Several compared hearing aid users to normal hearing peers rather than individuals with hearing loss.

Aim 1

Compare fall metrics in hearing aid users to non-users.

- ▶ Primary outcome measure: prevalence of falls as self-reported via survey (question 1 of Fall Risk Questionnaire).
- ▶ Secondary outcome measure: proportion of each group considered a fall risk (>3 on FRQ).

Aim 2

Examine the relationship between specific covariates (risk factors) and fall outcomes.

- ▶ Degree of hearing loss, duration of hearing loss and duration of hearing aid use as well as medical comorbidities (medication usage, diabetes, stroke, cognitive decline) are all potentially associated with the hearing aid/fall association

Study Design

- ▶ A cross-sectional study surveying individuals with hearing loss about their fall history and hearing aid use.

Population

Inclusion criteria:

- Individuals aged 60+ with documented bilateral SNHL
- Cognitive and linguistic capacity to complete questionnaire

Exclusion Criteria:

- Knee/hip replacement in past year
- Non-ambulatory individuals or those requiring prosthetics to ambulate
- Actively taking meclizine
- Individuals with a vestibular dysfunction diagnosis
- Those with degenerative neurological disease (e.g., Parkinson's)
- Individuals who are legally blind

Methods

- ▶ University of Colorado Hospital Audiology department EHR queried for individuals who were 60+ with diagnosis code for bilateral sensorineural hearing loss
- ▶ Email invitation sent to participate in REDCap Survey
- ▶ Following IC and survey completion, EHR was reviewed for degree of hearing loss, medical comorbidities and medication usage

Survey Composition

- ▶ Fall Risk Questionnaire (FRQ)
 - ▶ 4 “yes” answers = fall-risk
- ▶ Dizziness Handicap Inventory-Screener
- ▶ 6 additional questions related to hearing aid usage and duration

Fall Risk Questionnaire (FRQ)

- | Yes | No | |
|-----|----|---|
| | | 1. I have fallen in the last 6 months. |
| | | 2. I am worried about falling. |
| | | 3. Sometimes, I feel unsteady when I am walking. |
| | | 4. I steady myself by holding onto furniture when walking at home. |
| | | 5. I use or have been advised to use a cane or walker to get around safely |
| | | 6. I need to push with my hands to stand up from a chair. |
| | | 7. I have some trouble stepping up onto a curb. |
| | | 8. I often have to rush to the toilet. |
| | | 9. I have lost some feeling in my feet. |
| | | 10. I take medicine that sometimes makes me feel light-headed or more tired than usual. |
| | | 11. I take medicine to help me sleep or improve my mood. |
| | | 12. I often feel sad or depressed. |

Developed by Rubenstein et al. (2011).

If you answered **YES** to question 1, approximately how many falls have you had in the past 6 months? _____

Approximately how many years have you had hearing loss? _____

Do you wear hearing aids? Yes No

If yes, on average, how many hours do you wear them each day? _____

How many years have you had hearing aids? _____

If you have experienced a fall in the past 6 months, were you wearing your hearing aids when you fell? Yes No

Medication classification: ARS

- ▶ Rudolph et al. showed that higher ARS values were associated with higher risk falls, dizziness and confusion in adults over the age of 65
- ▶ Provides better detail than just the number of medications an individual is prescribed

Magellan Anticholinergic Risk Scale

1 POINT	
GENERIC	BRAND
Alprazolam	Xanax®
Aripiprazole	Abilify®
Asenapine	Saphris®
Captopril	Capoten®
Chlordiazepoxide	Librium®
Chlorthalidone	Diuril®
Clonazepam	Klonopin®
Clorazepate	Tranxene®
Codeine	--
Diazepam	Valium®
Digoxin	Lanoxin®
Dipyridamole	Persantine®
Famotidine	Pepcid®
Fentanyl	Duragesic®
Fluoxetine	Prozac®
Flurazepam	Dalmane®
Fluvoxamine	Luvox®
Furosemide	Lasix®
Haloperidol	Haldol®
Hydralazine	Apresoline®
Iloperidone	Fanapt®
Isosorbide	Imdur®
Mirtazapine	Remeron®
Morphine	MS Contin®
Nifedipine	Procardia®
Nizatidine	Axid®
Oxycodone	Oxycontin®
Paroxetine	Paxil®
Prednisone	Deltasone®
Quinidine	Quinaglute®
Ranitidine	Zantac®
Risperidone	Risperdal®
Temazepam	Restoril®
Tramadol	Ultram®
Trazodone	Desyrel®
Triamterene	Dyrenium®
Warfarin	Coumadin®
Ziprasidone	Geodon®

2 POINTS	
GENERIC	BRAND
Amantadine	Symmetrel®
Baclofen	Lioresal®
Carbamazepine	Tegretol®
Carisoprodol	Soma®
Cetirizine	Zyrtec®
Cimetidine	Tagamet®
Clidinium & Chlordiazepoxide	Librax®
Cyclizine	Cyclivert®
Cyclobenzaprine	Flexeril®
Cyproheptadine	Periactin®
Disopyramide	Norpace®
Fluphenazine	Prolixin®
Loperamide	Diamode®
Loratadine	Claritin®
Loxapine	Loxitane®
Meperidine	Demerol®
Methocarbamol	Robaxin®
Oxcarbazepine	Trileptal®
Pimozide	Orap®
Prochlorperazine	Compazine®
Pseudoephedrine	Sudafed®
Quetiapine	Seroquel®
Trimethobenzamide	Tigan®

3 POINTS	
GENERIC	BRAND
Amitriptyline	Elavil®
Amoxapine	Asenden®
Atropine	--
Benzotropine	Cogentin®
Brompheniramine	Respa-BR®
Carbinoxamine	Arbinox®
Chlorpheniramine	Chlor-Trimeton®
Chlorpromazine	Thorazine®
Clemastine	Tavist®
Clomipramine	Anafranil®
Clozapine	Clozaril®
Darifenacin	Enablex®
Desipramine	Norpramin®
Dicyclomine	Bentyl®
Dimenhydrinate	Dramamine®
Diphenhydramine	Benadryl®
Doxepin	Sinequan®
Flavoxate	Urispas®
Glycopyrrolate	Robinul®
Hydroxyzine	Atarax®
Hyoscyamine	Anaspaz®
Imipramine	Tofranil®
Meclizine	Antivert®
Mepenzolate	Cantil®
Methscopolamine	Pamine®
Nortriptyline	Pamelor®
Olanzapine	Zyprexa®
Orphenadrine	Norflex®
Oxybutynin	Ditropan®
Perphenazine	Trilafon®
Promethazine	Phenergan®
Propantheline	Pro-Banthine®
Protriptyline	Vivactil®
Scopolamine	Transderm Scop®
Thioridazine	Mellaril®
Thiothixene	Navane®
Tizanidine	Zanaflex®
Tolterodine	Detrol®
Trifluoperazine	Stelazine®
Trihexyphenidyl	Artane®
Trimipramine	Surmontil®
Tropium	Sanctura®

KEY

1 Point = low risk of anticholinergic Side effects

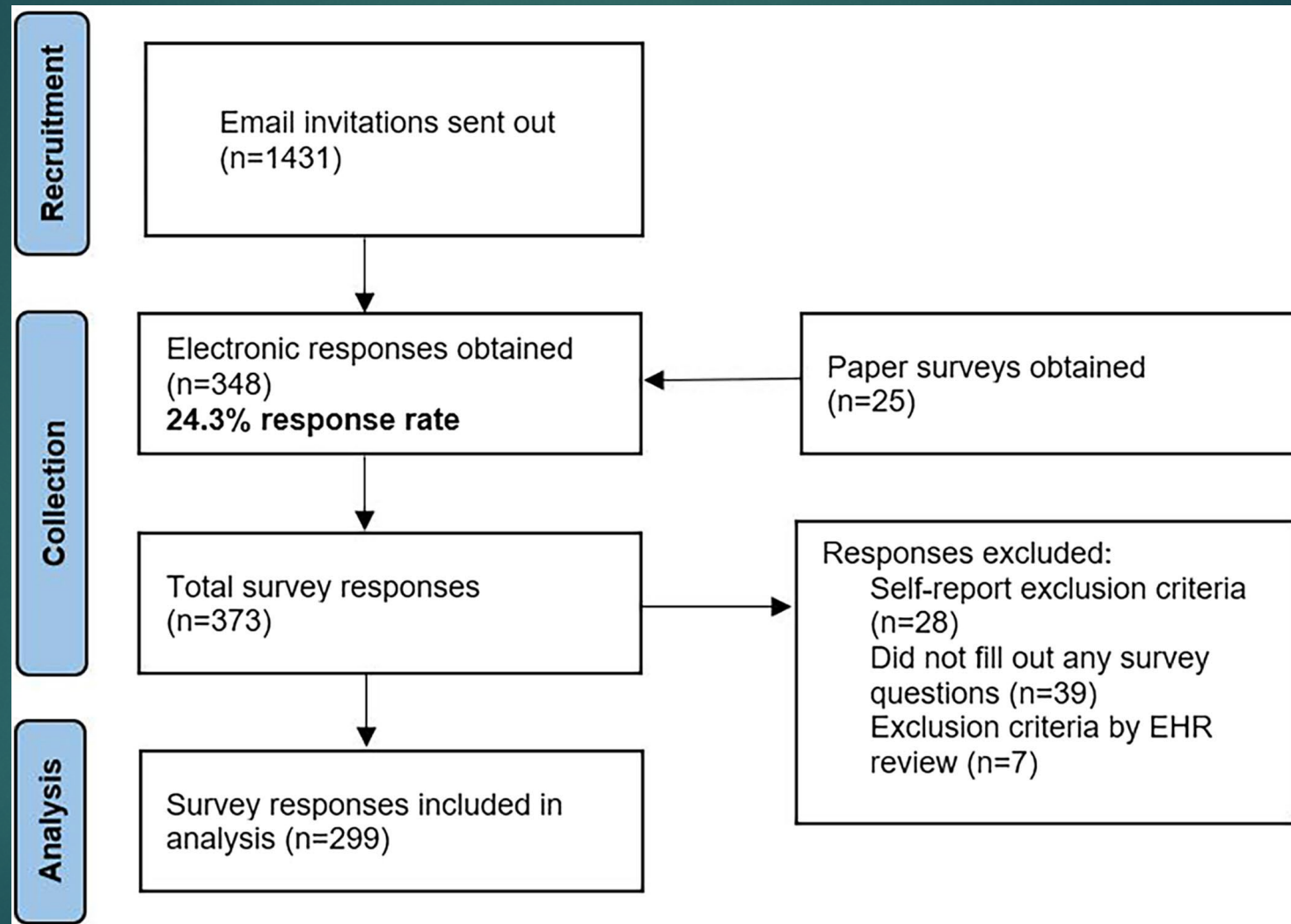
2 Points = moderate risk of Anticholinergic side effects

3 Points = high risk of Anticholinergic side effects

Hearing aid use groups

- ▶ Any use vs none
- ▶ Consistent users vs inconsistent/no use
 - ▶ Consistent HA users reported at least 4 hrs/day of average wear time for 1 year or longer
- ▶ So for analysis we have 2 outcomes (fall prevalence and fall-risk) and 2 interventions (any hearing aid use, consistent hearing aid use)

Data collection



Descriptive statistics of all participants and differentiated by consistent vs inconsistent/non-use

Characteristic	All participants (n = 299)	Consistent users (n = 181)	Inconsistent/non-users (n = 118)	p-value
Demographics				
Age	73.8 (6.7)	74.8 (6.6)	72.5 (6.6)	0.004
Female sex	51.2%	52.8%	50.9%	0.74
White race	96.1%	97.1%	94.7%	0.38
Fall characteristics				
Any fall ^a	26.4%	19.3%	37.3%	<0.001
Fall-risk ^a	31.3%	24.0%	42.4%	<0.001
Hearing characteristics				
Any HA use ^a	68.8%	–	–	–
Consistent HA use ^a	60.5%	–	–	–
Hearing loss severity (dB)	35.9 (15.3)	40.7 (15.4)	28.7 (11.7)	<0.001
Hearing loss asymmetry (dB)	6.6 (11.8)	7.1 (11.6)	5.8 (12.1)	0.39
Hearing loss duration (years) ^a	12.2 (14.0)	14.7 (15.0)	8.0 (11.1)	<0.001
Comorbidities				
ARS score	1.1 (1.7)	1.1 (1.7)	1.2 (1.7)	0.40
Diabetes	15.8%	14.8%	17.3%	0.58
Stroke	4.7%	7.1%	0.9%	0.02
Cognitive decline	2.1%	1.8%	2.8%	0.58
Previous falls	3.2%	3.0%	3.7%	0.74
Positional dizziness ^a	11.8	11.0%	12.9%	0.62

Abbreviations: ARS, anticholinergic risk scale; dB, decibel; HA, hearing aid.

^aIndicates any characteristic collected by participant self-report. p-values are for Welch's *t*-tests (continuous variables) and chi-squared tests (categorical variables) between consistent and inconsistent/non users, significant p-values are in bold.

Collected covariates by fall-status and fall-risk classification

Characteristic	No falls (n = 220)	Any falls (n = 79)	p-value	Not at fall risk (n = 197)	Fall risk (n = 92)	p-value
Demographics						
Age	74.3 (6.8)	72.4 (6.4)	0.03	74.0 (6.5)	73.4 (7.0)	0.46
Female sex	47%	50.6%	0.57	53.8%	47.8%	0.34
White race	97.0%	94.9%	0.4	96.4%	95.6%	0.96
Hearing characteristics						
Any HA use ^a	72.7%	56.9%	0.01	74.5%	54.8%	<0.001
Consistent HA use ^a	66.4%	44.3%	<0.00	66.6%	46.2%	<0.001
Hearing loss severity (dB)	35.9 (15.3)	35.9 (15.1)	0.99	35.9 (15.9)	35.9 (13.7)	0.99
Hearing loss asymmetry (dB)	5.9 (9.2)	8.4 (16.7)	0.2	6.8 (12.7)	6.0 (9.6)	0.55
Hearing loss duration (years) ^a	12.3 (14.6)	11.9 (12.3)	0.8	12.2 (14.8)	11.9 (12.2)	0.85
Comorbidities						
ARS score	1.0 (1.5)	1.6 (2.0)	0.03	0.9 (1.5)	1.7 (2.0)	0.001
Diabetes	14.8%	18.4%	0.46	12.8%	22.2%	0.04
Stroke	3.6%	6.3%	0.36	4.3%	5.6%	0.64
Cognitive decline	1.8%	2.5%	0.74	1.6%	3.3%	0.36
Previous falls	1.4%	7.6%	0.007	1.6%	6.7%	0.03
Positional dizziness ^a	15.2%	10.8%	0.27	5.0%	26.9%	<0.001
Use glasses ^a	78.7%	70.5%	0.14	76.5%	76.1%	0.94

Abbreviations: ARS, anticholinergic risk scale; dB, decibel; HA, hearing aid.

^aIndicates any characteristic collected by participant self-report. Continuous variables are shown by their means (standard deviations) and categorical variables are shown by proportion. *p*-values are for Welch's *t*-tests (continuous variables) and chi-squared tests (categorical variables), significant *p*-values are in bold.

Aim 1: How does fall prevalence/risk vary by hearing aid use?

Aim 2: how do fall risk factors affect fall outcomes?

Logistic Regression Modelling

- ▶ Model 1: Crude/Unadjusted
- ▶ Model 2: Multivariate LR adjusted by common risk factors for falls (decided *a priori*)
 - ▶ Adjusted for age, sex, hearing loss severity (PTA) and medications (ARS score)
- ▶ Model 3: Forward Stepwise LR with all collected covariates

Model Summaries for Fall Prevalence

	Any HA use	Consistent HA use
	Odds ratio (95% CI)	Odds ratio (95% CI)
	(Referenced to no HA use)	(Referenced to no/ inconsistent HA use)
Fall prevalence		
Unadjusted/ crude model	0.50 (0.29–0.85) $p = 0.01$	0.40 (0.24–0.68) $p < 0.001$
Adjusted model ^a	0.48 (0.26–0.90) $p = 0.02$	0.35 (0.19–0.67) $p < 0.001$
Stepwise model ^b	0.51 (0.28–0.93) $p = 0.03$	0.43 (0.24–0.77) $p = 0.005$

Model Summaries for Fall Risk

	Any HA use	Consistent HA use
	Odds ratio (95% CI)	Odds ratio (95% CI)
	(Referenced to no HA use)	(Referenced to no/ inconsistent HA use)
Fall risk		
Unadjusted/ crude model	0.42 (0.25–0.70) $p < 0.001$	0.43 (0.26–0.71) $p < 0.001$
Adjusted model ^a	0.36 (0.19–0.66) $p < 0.001$	0.32 (0.12–0.59) $p < 0.001$
Stepwise model ^c	0.41 (0.22–0.76) $p < 0.004$	0.38 (0.21–0.69) $p < 0.001$

Conclusions

Consistent hearing aid use is associated with a significantly lower odds of falling (between 45-65% lower), even after adjusting for age, medications, dizziness and previous falls

Consistent hearing aid use is associated with a significantly lower odds of being a fall-risk (between 30-65% lower), even after adjusting for age, medications, HL severity, dizziness and previous falls

Discussion:

- ▶ Fallers were **younger**, but had higher ARS scores (more med usage), reported more dizziness and a higher proportion of previous falls
- ▶ Hearing aid users were older and had greater degrees of hearing loss (which should increase their fall risk), but still reported significantly fewer falls than non-users (21.95% vs 36.17%).
- ▶ Many variables which should be risk factors for falls were not significantly different
 - ▶ Female sex, hearing loss severity, cognitive decline
- ▶ All models showed stronger associations for consistent hearing aid users suggesting greater reduction in risk with greater amounts of hearing aid use.

Discussion: are HA users just healthier individuals?

- ▶ HA users were older, had more hearing loss, and had higher rates of stroke
- ▶ No difference in medication usage (ARS), diabetes, cognitive decline or previous falls
- ▶ Non-users did report more dizziness

Limitations

- ▶ Association not causation
- ▶ Generalizability
- ▶ Selection and recall bias
 - ▶ self-reported outcome measures
- ▶ Unmeasured covariates

Future Research

- ▶ Which mechanism(s) are contributing to the observed relationship?
 - ▶ Longitudinal studies and/or pre-post studies
 - ▶ Include other outcome measures of postural stability and vestibular and cognitive function
- ▶ RCT: randomly assign HAs as intervention and compare to fall rates in controls
 - ▶ Can draw stronger conclusions
 - ▶ Reduces chance of unmeasured covariates affecting results

Implications for Clinical Practice

Audiologists

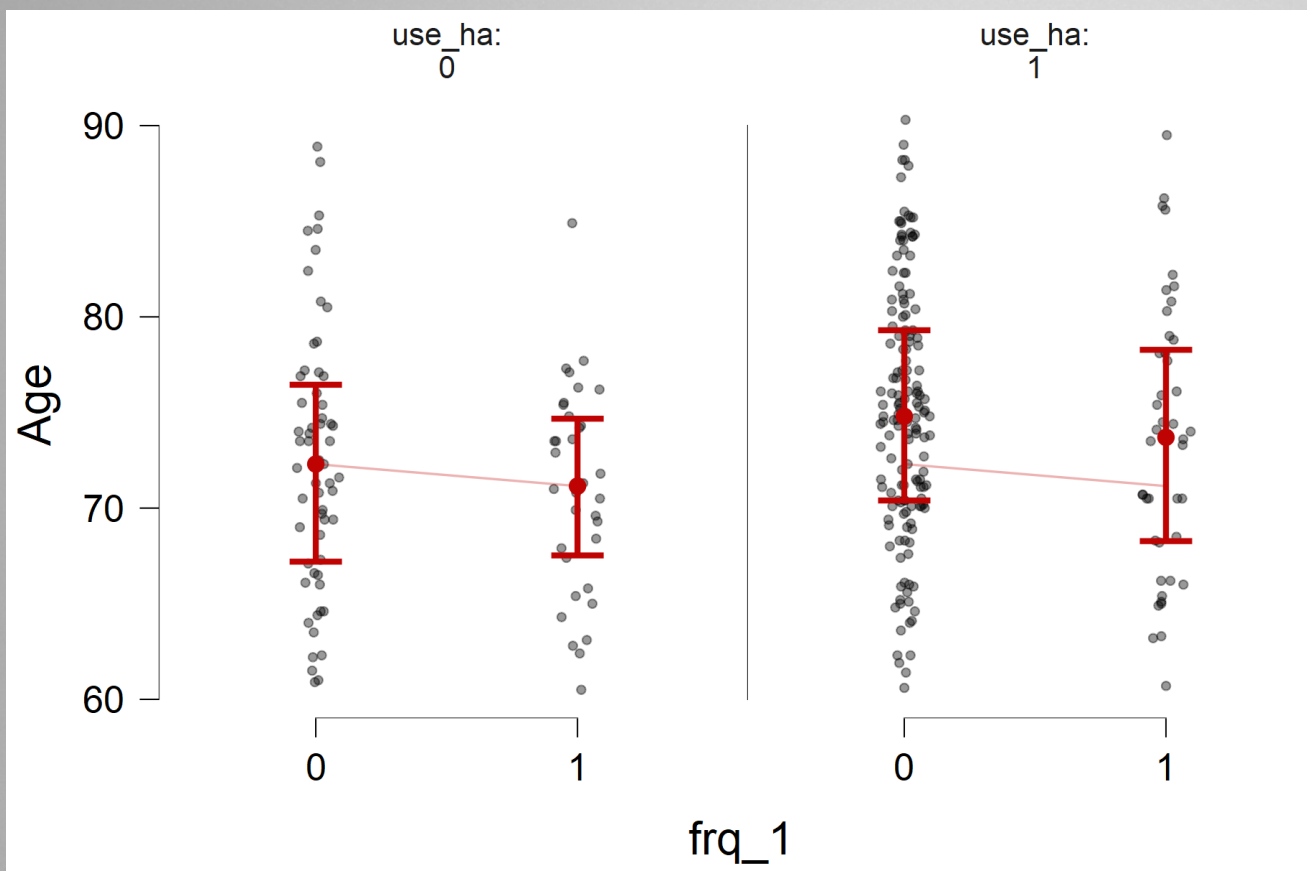
- ▶ Supports the recommendation that a potential benefit to obtaining hearing aids is a reduced probability of falling
- ▶ Encourage consistent hearing aid use with the aim of patients wearing their hearing aids for at least 4 hours each day

Fall Prevention Programs

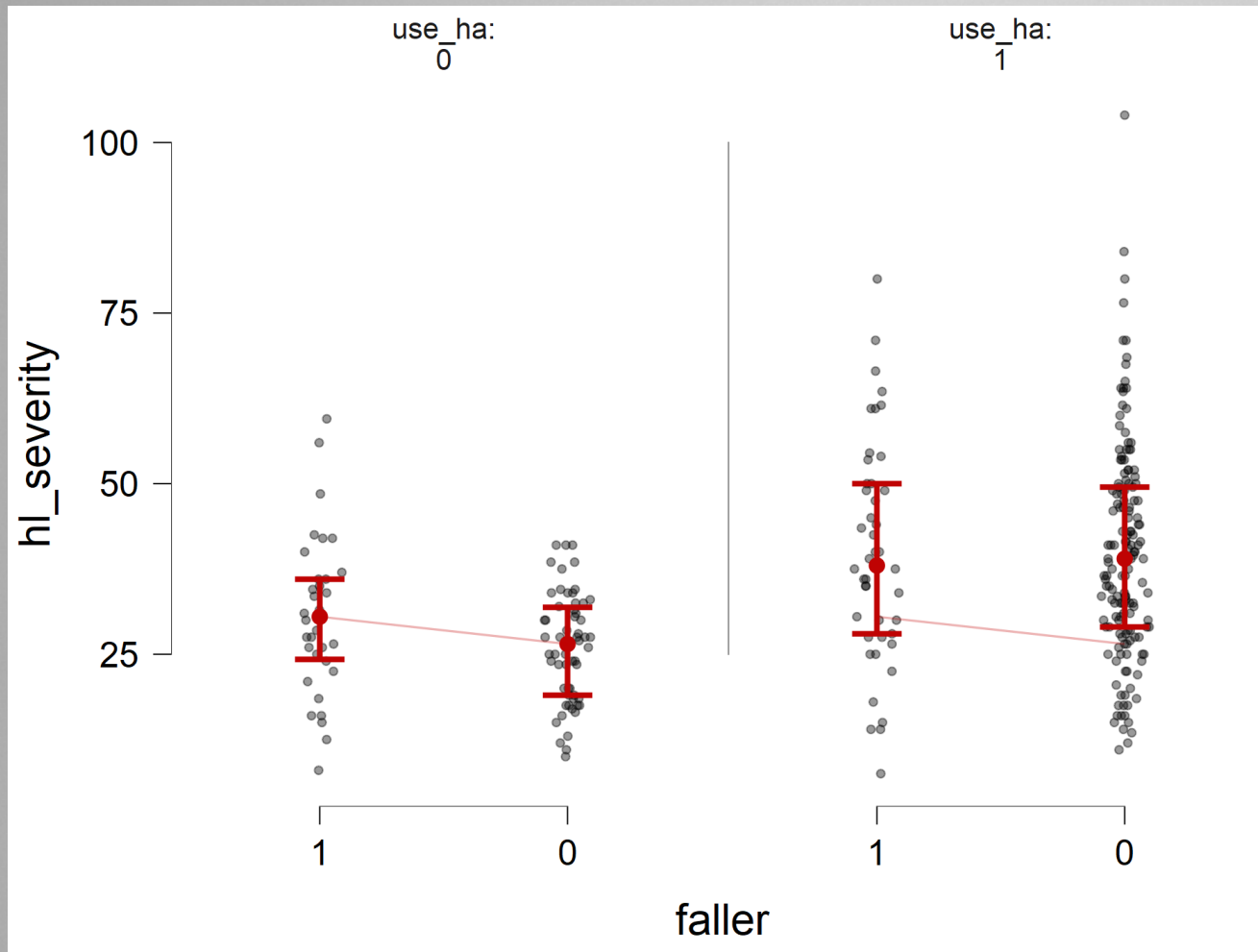
- ▶ Add hearing loss to the list of potentially modifiable risk factors for falls
- ▶ Should consider adding a hearing screening to assessment battery (if not already included) and refer those that do not pass to an audiologist
- ▶ Counsel on the potential benefits of addressing any identified hearing loss regarding fall risk reduction



Questions?



Age
separated
by HA
status



HL severity
separated
by HA
status

Falls by glasses use

Contingency Tables

frq_1	glasses		Total
	0	1	
0	46	170	216
1	23	55	78
Total	69	225	294

Chi-Squared Tests

	Value	df	p
X ²	2.141	1	0.143
N	294		

frq_fallrisk	glasses		Total
	0	1	
0	47	153	200
1	22	70	92
Total	69	223	292

Chi-Squared Tests

	Value	df	p
X ²	0.006	1	0.938
N	292		

	Estimate	Standard Error	Odds Ratio	z	Wald Test			95% Confidence interval (odds ratio scale)	
					Wald Statistic	df	p	Lower bound	Upper bound
(Intercept)	1.351	1.561	3.861	0.865	0.749	1	0.387	0.181	82.357
glasses	−0.219	0.316	0.803	−0.693	0.481	1	0.488	0.433	1.492
sex	−0.005	0.280	0.995	−0.016	2.716e −4	1	0.987	0.575	1.724
Age	−0.035	0.022	0.965	−1.597	2.550	1	0.110	0.924	1.008
ars	0.171	0.077	1.186	2.210	4.885	1	0.027	1.020	1.380
hl_severity	0.007	0.009	1.007	0.776	0.603	1	0.438	0.989	1.026

Note. frq_1 level '1' coded as class 1.

Measure of HA
benefit-
change in SII

