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## Review Articles

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Toll EC, Nunez DA. Diagnosis and treatment of acute otitis media: review. *J Laryngol Otol* 2012;**126**: 976–983. http://dx.doi.org/10.1017/S0022215112001326

## Main Article

Kanegaonkar RG, Amin K, Clarke M. The contribution of hearing to normal balance. *J Laryngol Otol* 2012; **126**:984–988. http://dx.doi.org/10.1017/S002221511200179X

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**REVIEW ARTICLE**

# The relationship between vestibular aqueduct diameter and sensorineural hearing loss is linear: a review and meta-analysis of large case series

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## Abstract

*Introduction*: Inner ear homeostasis is dependent on the vestibular aqueduct and its content, the endolymphatic duct. Narrow and enlarged vestibular aqueducts have both been associated with hearing loss in Ménière's and large vestibular aqueduct syndromes. This review investigated the correlation between vestibular aqueduct diameter and pure tone average, and the effect of measurement site (i.e. the midpoint or the external aperture).

*Materials and methods*: A systematic review of the literature and meta-analysis of large case series published on the Allied and Complementary Medicine, British Nursing Index, Cumulative Index to Nursing and Allied Health, Embase, Health Business Elite, Health Management Information Consortium, Medline, PsycInfo and PubMed databases. References and personal books were also scrutinised.

*Results*: A linear relationship between vestibular aqueduct diameter and hearing loss was observed, with a projected increase of 6 dBHL per unit of vestibular aqueduct diameter (95 per cent confidence interval, 2–10; $p = 0.003$). This relationship was independent of measurement site.

*Discussion*: This dose-dependent or linear relationship supports the role of flow and/or pressure change as aetiological factors in the pathogenesis of hearing loss, as per Poiseuille's law. This aetiological association is strengthened by the fact that the observed relationship is independent of measurement site.

**Key words:** Skull Base; Otology; Paediatric Ears/Otology; Endolymph Flow; Pressure

## Introduction

The vestibular aqueduct is a canal in the otic capsule of the temporal bone. It contains the endolymphatic sac and duct and is therefore considered a vital element of inner ear pressure and fluid homeostasis.[1–3] The endolymphatic sac and duct together with their physical restriction have been implicated in the pathogenesis of inner ear dysfunction, such as the sensorineural hearing loss and vertigo seen in Ménière's disease.[1–3]

The association between hearing loss and an enlarged vestibular aqueduct (with associated enlarged endolymphatic sac and duct) has been named the large vestibular aqueduct syndrome.[4–6] It is the most common structural cause of sensorineural hearing loss in childhood, and often occurs in association with other inner ear anomalies or systemic syndromes.[1,4,5,7] Conversely, many studies have reported a smaller vestibular aqueduct width in Ménière's disease patients.[1–3]

Studies have investigated the relationship between vestibular aqueduct diameter and various aspects of hearing loss.[8,9] The significance of the nature of this relationship lies in its implications for the pathogenesis of hearing loss. There are many theories regarding the pathogenesis of large vestibular aqueduct syndrome, including the hyperosmolar reflux theories and back pressure wave theories.

This review aimed to determine the exact nature of the relationship between vestibular aqueduct diameter and an aspect of hearing loss, pure tone average: the average frequency at 0.5, 1 and 2 kHz. Poiseuille's law states that flow and/or change in pressure is proportional to the fourth power of the radius of a cylindrical pipe. This review sought to investigate whether this law explains the relationship between hearing loss and vertigo symptoms in such conditions as Ménière's disease and large vestibular aqueduct syndrome.

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At the outset, it was postulated that, because of Poiseuille's law, the pure tone average would demonstrate a linear relationship with vestibular aqueduct diameter regardless of measurement site (i.e. external aperture or midpoint).

## Materials and methods

In order to determine the nature of the relationship between vestibular aqueduct diameter and hearing loss, a literature review was conducted with the objective of performing a meta-analysis.

### *Data sources and search strategy*

A comprehensive search was undertaken of the Allied and Complementary Medicine ('AMED'), British Nursing Index ('BNI'), Cumulative Index to Nursing and Allied Health ('CINAHL'), Embase, Health Business Elite, Health Management Information Consortium ('HMIC'), Medline, PsycInfo and PubMed databases.

The search strategy, which included key words and associated medical subject and Emtree headings, was: '(large* OR wide* OR enlarg*) AND (vestibular aqueduct*) AND (diameter* OR width) AND audiogram'.

There were no limits or filters placed on the searches to minimise bias due to time, language or context. The references of all articles were reviewed, as were personal books and files. Authors were contacted for clarification when required.

### *Inclusion criteria*

The literature search included articles reporting the vestibular aqueduct diameter at either the external aperture or the midpoint, together with either (1) the respective pure tone average (i.e. the average hearing sensitivity at 0.5, 1 and 2 kHz) or (2) the raw data at these frequencies.

### *Statistical analysis*

This was guided by input from a senior medical statistics lecturer at a university teaching hospital (see Acknowledgements).

Data were analysed using the Statistical Package for the Social Sciences version 16.0 software program (SPSS Inc, Chicago, Illinois, USA), including three-dimensional general linear models.

## Results

### *Study selection*

The literature search yielded 36 citations. Twelve of these were considered potentially eligible for inclusion in the review, based on the abstract and/or full text (Figure 1). Further evaluation of the full manuscripts excluded nine studies.[10–18]

### *Study characteristics*

Three articles were included in the review. These were all large case series reporting a total of 61 patients' vestibular aqueduct diameters and pure tone averages

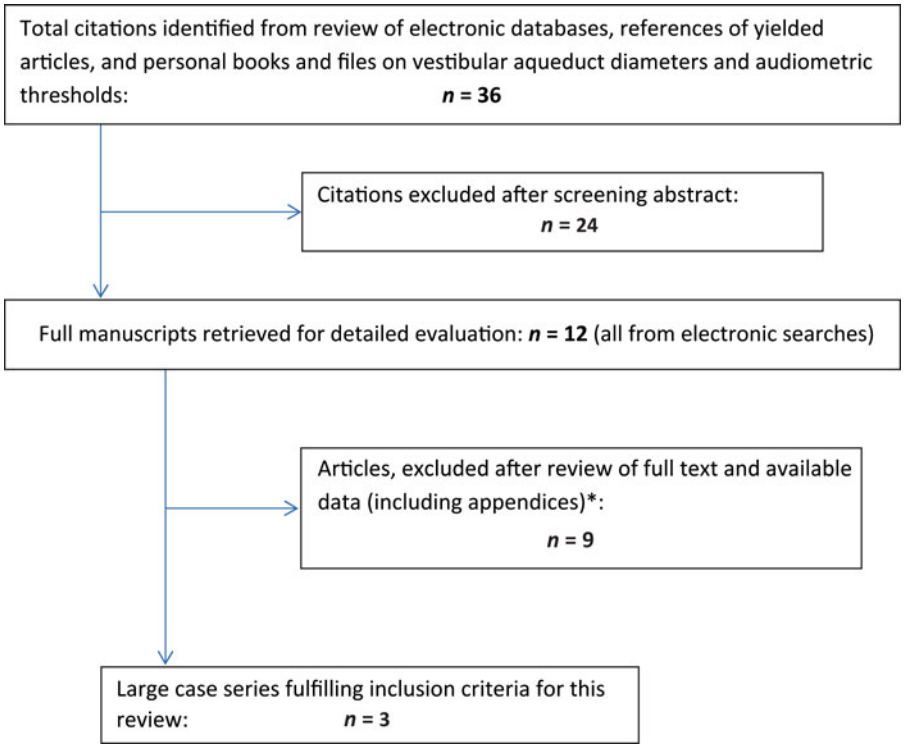


FIG. 1

Study selection process. *No width or diameter measurements with respective audiometry data (either as pure tone averages or raw hearing thresholds).

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(or the respective audiometric thresholds from which this average could be derived) (see Table I).

One study evaluated the vestibular aqueduct diameters of patients with unilateral, sudden, sensorineural hearing loss, together with those of 47 control subjects.[1]

The second study investigated the effect of corticosteroids on the audiograms of patients with large vestibular aqueduct syndrome.[5]

The final study was a case series of patients with normal and large vestibular aqueducts, with and without sensorineural hearing loss.[6]

### *Descriptive statistics*

The vestibular aqueduct diameters included in the analysis ranged from 0.3 mm at the midpoint (pure tone average, 85 dBHL) to 11.11 mm at the external aperture (pure tone average, 90 dBHL). Hearing as assessed by pure tone average ranged from 0 dBHL (in two patients with vestibular aqueduct diameters of 1 and 4 mm, variously, at the midpoint) to 116 dBHL (in a patient with a vestibular aqueduct diameter of 7.78 at the external aperture). The mean pure tone average was 78.36 dBHL (standard deviation (SD) 25.46 dBHL) and the mean vestibular aqueduct diameter was 3.71 mm (SD 2.57 mm).

### *Meta-analysis*

Data were analysed to test the effect of interaction between vestibular aqueduct diameter (measured in mm) and pure tone average (measured in dBHL). A linear relationship was found: the pure tone average threshold (beta) increased by 6 dBHL per unit of vestibular aqueduct diameter (95 per cent confidence interval (CI) = 2–10 dBHL; $p = 0.003$).

## Discussion

### *Principal meta-analysis findings*

This review represents the largest correlation of vestibular aqueduct diameter and pure tone average data published to date. Table I summarises the meta-analysis of single institution case series. A linear relationship was observed between vestibular aqueduct diameter and pure tone average, with a projected increase of 6 dBHL per unit of vestibular aqueduct diameter (95 per cent CI = 2–10 dBHL; $p = 0.003$). The vestibular aqueduct diameter measurements included in the individual series, and in the combined analysis, were taken both at the external aperture and at the midpoint. The derived dose-dependent relationship supports consideration of endolymphatic flow and/or pressure change as aetiological factors in sensorineural hearing loss.

### *Strengths and limitations*

The strength of this meta-analysis lies in its clinically relevant and focused question. Information bias was reduced by utilising comprehensive searches of many data sources. Articles in languages other than English were considered, and complete records were inspected.

TABLE I
INCLUDED STUDIES ASSESSING VESTIBULAR AQUEDUCT DIAMETER AND AUDIOMETRIC THRESHOLD

| Study | Design | Pts (M:F; *n*) | Age range (y) | VA mt site (pts; *n*) | VA diam range | | | | VA diam *vs* SNHL analysis | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Minimum | | Maximum | | | |
| | | | | | mm | PTA (dBHL) | mm | PTA (dBHL) | | |
| Sugiura *et al.*[1] | Case series & case–control study | 19 (12:7) | 22–79 | EA (19) | 0.5 | 95 | 1.4 | 113 | VA wider in sudden SNHL than controls (at MP $p < 0.05$, at EA $p < 0.0005$) | Controls all had conductive hearing loss; no mention of matching strategy |
| | | | | MP (19) | 0.3 | 85 | 0.9 | 113 | | |
| Lin *et al.*[5] | Case series | 16 (12:4) | 1–4 | EA (32) | 3.85 | 82 | 11.11 | 90 | No correlation: VA diam *vs* primordial HL ($r = 0.104$, $p = 0.572$) or *vs* sudden deterioration level ($r = 0.289$; $p = 0.317$) | 85% of patients had response to corticosteroids; no use of controls |
| Emmett[6] | Case series | 26 (12:14) | 3–44 | MP (50) | 1 | 0 | 6 | 80 | None performed | Descriptive statistics only, correlation not assessed |
| | | | | | 1 | 12 | 6 | 82 | | |
| | | | | | 1 | 73 | | | | |

Pts = patients; M = male; F = female; y = years; VA = vestibular aqueduct; mt = measurement; diam = diameter; PTA = pure tone average; SNHL = sensorineural hearing loss; EA = external aperture; MP = midpoint; HL = hearing loss

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The meta-analysis was homogeneous in that all data were from large, single-centre case series of patients with sensorineural hearing loss.

This meta-analysis is the largest of its type to date, which increases its power. The inclusion criteria set out at the beginning of the review were strictly adhered to, thereby minimising selection bias. The level of statistical significance of the correlation was high, and although the confidence intervals of the derived beta were wide, they did not reach zero.

This meta-analysis does have some limitations, including possibly the heterogeneity of the series, which ranged from infants to the elderly, with hearing thresholds ranging from normal to profound hearing loss. This could potentially introduce error. However, all patients had sensorineural hearing loss, and the comprehensiveness of this meta-analysis is also a strength. The range of vestibular aqueduct diameters was also very wide. The case series used CT scanning to assess vestibular aqueduct diameters, although magnetic resonance imaging is considered more accurate in assessing endolymphatic sac and duct diameter.

### *Comparison with other studies*

The range of vestibular aqueduct diameters and pure tone averages identified by this review is wider than that of other studies investigating vestibular aqueduct diameter and sensorineural hearing loss. Other studies have attempted to assess the correlation between vestibular aqueduct diameter and aspects of sensorineural hearing loss.[1,5,8,9,18] One study found wider vestibular aqueduct diameters in sudden sensorineural hearing loss patients than in controls, while other authors found a correlation between vestibular aqueduct diameter and progressive hearing loss, and also between vestibular aqueduct diameter measured at the external aperture and hearing loss frequency and severity.[1,8,9,12] In contrast, smaller studies have failed to detect a correlation between hearing loss and endolymphatic sac or duct size.[17]

The current meta-analysis is unique in finding a highly statistically significant, linear relationship between pure tone average (in dBHL) and vestibular aqueduct diameter (in mm) measured both at the external aperture and the midpoint. A smaller study found no correlation between vestibular aqueduct midpoint diameters and audiometric parameters.[18] Correlation at both sites is explained by Poiseuille's law. There is also a strong index of biological plausibility related to observation of flow.

### *Clinical implications*

This review and meta-analysis gives support for sudden sensorineural hearing loss treatment modalities designed to alter the flow or pressure within the membranous labyrinth. These include such treatments as diuretics, corticosteroids and betahistine.

These types of medical treatment have been widely recommended as preferential to decompressive (i.e. pressure-relieving) surgery of the endolymphatic sac in patients with large vestibular aqueduct syndrome and Ménière's disease.

However, this review in itself found no new evidence to support medical treatment over surgical or vice versa.

## Conclusion

This review's meta-analysis is the first and largest of its type to date. Similarly to other studies, it found a correlation between vestibular aqueduct diameter and an aspect of hearing loss, namely (in this review) pure tone average. However, the review is unique in finding a linear relationship irrespective of site of vestibular aqueduct measurement. Combined analysis of external aperture and midpoint data resulted in an indeterminate 'unit' of vestibular aqueduct diameter which correlated very significantly with the pure tone average. Future research will seek to determine this unit, which could be used to ascertain prognosis.

## Acknowledgements

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**REVIEW ARTICLE**

# Diagnosis and treatment of acute otitis media: review

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## Abstract

*Background*: Acute otitis media is very common, but diagnostic criteria and treatment recommendations vary considerably.

*Methods*: Medline, the Cochrane Database of Systematic Reviews and the Cochrane Central Register of Controlled Trials were searched using the key words 'acute otitis media' AND 'diagnosis' OR 'diagnostic criteria' OR 'definition', and by combining the terms 'acute otitis media' AND 'guidelines'. PubMed was searched using the key words 'mastoiditis' and 'prevalence'.

*Results*: The 11 most recently published guidelines unanimously agreed that adequate analgesia should be prescribed in all cases. The majority recommended that routine antibiotic prescription should be avoided in mild to moderate cases and when there was diagnostic uncertainty in patients two years and older. Antibiotics were recommended in children two years and younger, most commonly a 5-day course of amoxicillin (or a macrolide in patients allergic to penicillin).

*Conclusion*: Level 1A evidence shows that selected cases of acute otitis media benefit from antibiotic prescription.

**Key words:** Otitis Media; Practice Guideline; Diagnosis; Therapy; Mastoiditis

## Introduction

Acute otitis media is one of the most common ear diseases affecting children in the UK, with 15 747 completed in-patient consultant episodes recorded in the 2009–2010 financial year.[1] How is it defined and diagnosed, and what is the evidence base? A 1981 survey found that, out of 43 acute otitis media studies identified, only 26 described their diagnostic criteria, and that there were 18 different sets of criteria.[2]

## Literature review

Medline, the Cochrane Database of Systematic Reviews and the Cochrane Central Register of Controlled Trials were searched to 6 August 2010, using the key words 'acute otitis media' in the title AND 'diagnosis' OR 'diagnostic criteria' OR 'definition' in the title or abstract, identifying 195 titles. Combining the terms 'acute otitis media' in the title AND 'guidelines' in the title or abstract produced 50 titles. The two authors independently judged the titles identified for relevance to the review. Full titles selected by either author were retrieved and their reference lists likewise searched for relevant articles.

Additional searches of the UK National Institute of Health and Clinical Excellence (NICE) and of the Agence Française de Sécurité Sanitaire des Produits de Santé (French Health Products Safety Agency) directory of guidelines, in November 2009 and May 2010, identified two guideline documents.

Relevant papers not identified by the search strategy but known to the senior author were also reviewed.

PubMed was searched for trials, meta-analyses, reviews, studies, government publications, guidelines and journal articles published between 1 January 2005 and 31 July 2011, with the key words 'mastoiditis' and 'prevalence', applying the following restrictions: human, child 0–18 years and English language publication. This yielded 39 titles, of which 14 were selected based on their relevance to the review. Ten of these 14 titles were excluded from further study, because they were not national studies, included less than 100 mastoiditis cases, or presented duplicate data.

## Diagnosis

The American Academy of Family Physicians and the American Academy of Pediatrics guidelines for the diagnosis and management of acute otitis media are

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based on a systematic review which defines diagnostic criteria for acute otitis media in children.[3,4] These criteria have three components: a history of acute onset of symptoms, signs of a middle-ear effusion and features of middle-ear inflammation. Otoscopic examination is highlighted as particularly important, including pneumatic otoscopy to identify middle-ear effusion.[3] Whilst the committee concluded from five studies that tympanometry and acoustic reflexometry were useful for diagnosing middle-ear effusion, a subsequently published trial found that tympanometry did not influence prescribing behaviour.[5–10] The single feature with the highest predictive value for diagnosing a middle-ear effusion consistent with acute otitis media was bulging of the tympanic membrane. The predictive value of a bulging tympanic membrane was increased when combined with impaired mobility and abnormal colouration.[11–13] These criteria have been adopted by the US Centers for Disease Control and Prevention.

The UK National Institute for Health and Clinical Excellence has published no guidelines on acute otitis media diagnosis; however, the UK National Health Service Clinical Knowledge Summaries publication cites diagnostic criteria drawn from a 2003 systematic review of six studies by Rothman *et al.*, which was not referenced by the American Academy of Family Physicians and American Academy of Pediatrics guidelines.[14,15] These National Health Service criteria are more specific about presenting symptoms (e.g. earache, pulling or rubbing the ear in younger children, and non-specific symptoms such as fever and irritability), but the examination findings stipulated are very similar to those in the American Academy of Family Physicians and American Academy of Pediatrics guidelines.

The 2008 Alberta Clinical Practice Guidelines highlight the importance of distinguishing between myringitis and acute otitis media, the main difference being the lack of tympanic membrane mobility seen in the latter condition.[16] Reduced mobility on pneumatic otoscopy is a key component of acute otitis media diagnosis in this document. The 2004 Cincinnati Children's Medical Center guidelines likewise recommend pneumatic otoscopy and tympanometry to improve diagnostic accuracy.[17] The British Columbia Medical Association, however, disapproves of diagnostic pneumatic otoscopy as it may cause severe pain.[18]

The acute otitis media diagnostic criteria presented in the French Health Products Safety Agency guidelines for antibiotic treatment of upper respiratory tract infections highlight the key importance of otoscopic findings obtained with good otoscopic technique.[19] The French guidelines and the American Academy of Family Physicians and American Academy of Pediatrics guidelines are almost identical. Otalgia and fever are heralded as the most classical clinical features of suppurative acute otitis media. Specified otoscopic findings are the absence of the light reflex, loss of normal contour and bulging of the tympanic membrane.

There is consensus in the literature on acute otitis media diagnostic criteria in childhood. In summary, these criteria comprise acute onset of otalgia or symptoms and signs consistent with otalgia (e.g. ear pulling or bulging of an erythematous tympanic membrane), together with loss of the light reflex or the presence of otorrhoea on otoscopy.

The implementation of uniform diagnostic criteria should help to improve diagnostic accuracy and enable more uniform treatment. Otolaryngologists are more accurate than other clinicians in diagnosing acute otitis media,[20,21] with lower false positive rates.[22] This improved accuracy is not related to the use of the oto-microscope.[23] Targeted training of healthcare practitioners in otoscopic examination improves diagnostic accuracy.[24] Such training is therefore justified, as accurate otoscopic examination is the core component required for reliable acute otitis media diagnosis.

## Treatment

The management of acute otitis media is controversial, with considerable differences in approach between Western countries. In 1990, the prevalence of antibiotic treatment for acute otitis media varied from 31 per cent in the Netherlands to more than 90 per cent in the USA, Australia, New Zealand, England and Wales.[25] The UK NICE guidelines recommend a strategy of either no antibiotics or delayed antibiotics for acute otitis media treatment, depending on severity, except in children under two years with bilateral otitis media or otorrhoea, in whom antibiotics are recommended.[26] These recommendations are based on a Cochrane review,[27] a meta-analysis,[28] and three large randomised, controlled trials (RCTs).[29–31]

The Dutch College of General Practitioners guidelines similarly advise withholding immediate antibiotic prescription in most cases, except in the 'systemically' ill child or when there are risk factors for acute otitis media complications.[32] These guidelines recommend that antibiotics be considered in children younger than two years in the presence of bilateral acute otitis media, and in children of any age presenting with otorrhoea, failure to improve after 72 hours of conservative treatment, or failure of otorrhoea to resolve spontaneously after one week.

The Scottish Intercollegiate Guideline Network guidance recommends that antibiotics not be routinely prescribed for acute otitis media in any child, irrespective of age.[33] However, this guidance is based on only one study, of children younger than two years.[34] The Scottish Intercollegiate Guideline Network guidance concludes that in all general practice based studies 25–75 per cent of children were excluded, presumably because clinicians felt that these children were too sick to be included in a trial. This means that regimes specifying no or delayed antibiotic prescription are appropriate only for milder acute otitis media cases, which

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account for as little as one in four cases presenting to UK general practitioners.

A 2004 Cochrane review found that the main benefit of immediate antibiotic treatment, compared with initial observation, was a 30 per cent relative reduction in pain at days 2 to 7.[27] However, in four of the studies reviewed, no reduction in pain was found from days 3 to 7. In Rovers and colleagues' meta-analysis, children under two years with bilateral acute otitis media or otorrhoea demonstrated the most benefit from immediate antibiotic treatment.[28] As regards adverse events, children receiving delayed prescription of antibiotics were 12 per cent less likely to develop diarrhoea than those receiving immediate antibiotics. Antibiotics side effects occurred in one in 24 children in the Cochrane review, with an increased risk of rash, diarrhoea and vomiting with immediate antibiotic treatment, compared with observation (risk ratio 1.37; 95 per cent confidence interval (CI) 1.34 to 1.39).

The American Academy of Family Physicians and American Academy of Pediatrics guidelines make different recommendations, and specify what antibiotics should be prescribed. In children aged six months or more, and who are otherwise healthy with non-severe symptoms and an uncertain diagnosis, initial observation is recommended. Antibiotics are recommended in all patients under six months with suspected acute otitis media.[3] These recommendations are based on three meta-analyses and an earlier version of the above Cochrane review.[4,27,35,36] The latter found that, for one child to receive any benefit, one would need to treat between seven and 20 children with antibiotics.

A meta-analysis published by the Agency for Healthcare Research and Quality found a 12 per cent reduction in the clinical failure rate (95 per cent CI, 3–22 per cent) within 2 to 7 days if amoxicillin or ampicillin was prescribed, compared with placebo or observation, with a 'number needed to treat' of eight.[4]

The Cincinnati Children's Hospital Medical Center guidelines differ from the American Academy of Family Physicians and American Academy of Pediatrics recommendations in that they advise antibiotics for all children under two years of age, rather than for those six months and under.[17] Parental involvement in antibiotic prescription decisions reduces antibiotic usage.[37,38] The French Health Products Safety Agency (French) guidelines similarly recommend antibiotics for all children under two years of age and in all cases with severe symptoms, defined as high fever or severe otalgia.[19] For children over two years with non-severe symptoms, a trial of no antibiotics is recommended, with re-evaluation in 48–72 hours. If symptoms are persistent at this stage, then antibiotics are recommended.

The Ontario Guidelines Advisory Committee recommends antibiotics in cases of symptomatic acute otitis media, but recommend deferring antibiotics for children of all ages with 'minimally symptomatic' or asymptomatic acute otitis media.[39] The British Columbia and Alberta guidelines recommend immediate antibiotics in all children under two years, but delayed antibiotics in children over two years, and then only if there is no improvement after 48–72 hours of conservative treatment.[16,18] A recent RCT that stringently assessed clinical signs in children under two years of age demonstrated that amoxicillin 90 mg/kg plus clavulanate 6.4 mg/kg improved the acute otitis media clinical resolution rate from 77 per cent to 96 per cent at 4 days.[40] The number needed to treat was five to six, similar to the seven to eight found by Damoiseaux *et al.*[34] However, the high complete resolution rate at day 4 contrasts markedly with the resolution rates of 41–68 per cent recorded in amoxicillin-treated groups.[34,41] This high early resolution rate supports the use of antibiotics, specifically amoxicillin-clavulanate, in children under two years.

The 2004 Israeli Medical Association guidelines on antibiotic usage in acute otitis media mirror the American Academy of Family Physicians and American Academy of Pediatrics guidelines.[42] Implementation of the former guidelines led to a significant reduction in antibiotic usage in children aged six months to five years.[42]

The 2010 Finnish Medical Society Duodecim guidelines differ considerably from others in that they recommend antibiotics as a rule for all patients regardless of age, although they stress that the diagnosis of acute otitis media must be reliable.[43] This recommendation is based on the rationale that antibiotics may speed up the resolution of symptoms in some children. Antibiotics are recommended in particular for cases of bilateral acute otitis media and children younger than two years. An option to withhold antibiotics in cases of mild inflammation is permitted, although close monitoring and follow up at 2 to 3 days is required.

Optimal analgesia is particularly important when treating acute otitis media.[3,16,18,26,32,43] Otalgia is viewed as a peripheral issue by some clinicians; however, in order to effectively treat acute otitis media, pain should be assessed and managed regardless of antibiotic use. The Finnish guidelines state that effective pain control is the key target of early intervention.[43] In trials assessing antibiotic therapy for acute otitis media, suboptimal analgesia may have had a significant effect on results, as pain is frequently used as an outcome measure.

The risk of developing mastoiditis is not increased by initial observation, compared with immediate antibiotic treatment, and the latter is not an absolute safeguard against complications.[4] Likewise, the incidence of bacterial meningitis is not influenced by whether the child is treated with immediate antibiotics or initial observation and symptomatic treatment. In the updated Cochrane review, which included studies of a total of 2928 children from high-income countries, only one case of mastoiditis was identified.[27]

Therefore, no comment could be made on the risk of developing this complication in patients receiving either immediate antibiotics or initial observation, except to say that it is a rare complication in the countries from which the studies originated.[27] This case of mastoiditis was one of two such cases reported in van Buchem and colleagues' 1985 study.[41] One case was excluded from the trial because mastoiditis was diagnosed at presentation, and the other case occurred in the 'no antibiotic' treatment group. The clinical trials demonstrating the efficacy of a 'no antibiotic' prescription policy in acute otitis media are too underpowered to assess the risk of developing mastoiditis.[44]

In the UK, hospital data revealed almost a doubling in admissions for mastoiditis or simple mastoidectomy in zero- to four-year-olds with the reduction in antibiotic prescription which occurred between 1993 and 2002.[45] This change almost exactly matches the difference in mastoiditis incidence between countries prescribing antibiotics in less than 80 per cent of acute otitis media cases versus those doing so in 100 per cent of such cases (in the late 1990s).[46] In Sweden from 1987 to 2004, there was a 37 and 52 per cent reduction in out-patient antibiotic prescriptions in children aged zero to four and five to 14 years, respectively, which was not accompanied by an increase in mastoiditis prevalence.[47] Thompson and colleagues conducted a 16-year, retrospective study which found that the annual incidence of childhood mastoiditis did not increase over that time; however, they calculated that universal adoption of a 'no antibiotics' prescription policy in the UK would lead to an extra 255 cases of childhood mastoiditis per year.[48] The risks of promoting antibacterial resistance by treating 4834 acute otitis media cases with antibiotics for each one mastoiditis case prevented should be clear to all clinicians.[48,49] Bodies which formulate antibiotic prescription guidelines need to present the implications of guidance strategies for the incidence of mastoiditis and other serious acute otitis media complications, in order to gain the support of clinicians and ultimately the public, who may in some instances have to deal with greater numbers of seriously ill children as a consequence.

Comparing different antibiotic regimes for acute otitis media is challenging. A 2002 review of acute otitis media treatment trial methodology by Dagan and McCracken found that trials comparing differing antibiotic regimes are often limited by significant flaws which could affect outcomes.[50]

One of the most frequent of these flaws is the lack of a clear, uniform definition of acute otitis media, leading to the potential inclusion of patients with otitis media with effusion (OME) rather than acute otitis media. In patients with OME, placebo treatment is likely to be as effective as antibiotics. The French Health Products Safety Agency (French) guidelines recommend amoxicillin-clavulanate or third generation cephalosporins as first-line therapy, with erythromycin for the penicillin-allergic.[19] The UK NICE and Scottish Intercollegiate Guideline Network guidelines refer clinicians to the most recent edition of the *British National Formulary* for specific antibiotic guidance.[26,33] The March 2010 edition of the *British National Formulary* recommended amoxicillin (or erythromycin if allergic to penicillin) as first-line therapy.[51] The American Academy of Family Physicians and American Academy of Pediatrics guidelines likewise recommend amoxicillin as the first-line agent for non-severe infections; however, in severe infections additional coverage of β-lactamase positive organisms with amoxicillin-clavulanate is also recommended. Cephalosporins or macrolides are recommended for patients allergic to penicillin.[3] The Dutch guidelines also recommend amoxicillin as the first agent of choice, or azithromycin (a specific macrolide) or co-trimoxazole in the penicillin-allergic.[32] The Finnish guidelines recommend amoxicillin or penicillin V as first-line therapy, with amoxicillin-clavulanate or cefuroxime as second-line therapy, and sulfa-trimethoprim, azithromycin and clarithromycin in the penicillin-allergic.[43] Amoxicillin is the first-line agent of choice in the Alberta guidelines, with azithromycin or clarithromycin for β-lactam hypersensitivity and amoxicillin-clavulanate or cefuroxime as second-line treatment. Erythromycin is highlighted as an antibiotic to avoid in acute otitis media due to high rates of resistance by haemophilus species and moraxella.[16] The Ontario guidelines particularly recommend the avoidance of macrolides in acute otitis media, although trimethoprim-sulfamethoxazole, azithromycin or cefprozil are recommended for penicillin-allergic patients.[39] These guidelines recommend amoxicillin as first-line therapy, with high-dose amoxicillin-clavulanate or cefuroxime if there is no improvement in 72 hours, and intra-muscular ceftriaxone as third-line therapy. Similarly, the British Columbia guidelines advise amoxicillin as first-line treatment, with amoxicillin-clavulanate in cases of treatment failure. However, in contrast to the other Canadian guidelines, erythromycin is recommended for penicillin-allergic patients, with clarithromycin as second-line treatment.[18]

The recommended duration of antibiotic therapy differs considerably amongst the guidelines reviewed. The optimum duration of antibiotic therapy for uncomplicated acute otitis media is recommended as 4 days by the NICE guidelines. No evidence is cited for this recommendation, but a 2000 Cochrane review found that treatment outcomes at 8 to 19 days were more favourable following a 5-day course of antibiotics, compared with courses of 8 to 10 days (summary odds ratio = 1.52, 95 per cent CI = 1.17–1.98; $n = 1524$).[52] The Scottish Intercollegiate Guideline Network recommends 5 days of antibiotics, when prescribed. The French recommendations differ by advising an 8 to 10 day course, referencing a RCT that showed significantly less efficacy for 5-day courses in children under two years of age.[53] A shorter course is however recommended for children over two years, based on a meta-analysis that found a 5-day course to be effective

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in this group.[54] The American Academy of Family Physicians and American Academy of Pediatrics guidelines are not fully consistent with either of these recommendations, advocating a 10-day course for younger children and those with severe symptoms, and a 5- to 7-day course for children aged six years or over with mild to moderate disease. The Alberta guidelines advocate a 5-day course for first-line therapy and a 10-day course for second-line therapy.[16] The Ontario guidelines recommend 5 days of antibiotics for children over two years and 10 days for children under two years.[39] The British Columbia guidelines recommend 5 days of amoxicillin, 10 days of erythromycin for penicillin-allergic patients, and 10 days of second-line antibiotics.[18] The Dutch guidelines recommend 7 days' initial treatment.[32]

The most consistent recommendation for first-line therapy is to prescribe analgesia in all cases but to avoid routine antibiotic prescription for mild to moderate cases and where there is diagnostic uncertainty in patients two years and older. Six of the 11 guidelines recommend prescribing antibiotics in children aged two years and younger, and an additional two make the same recommendation provided there is unilateral otorrhoea or bilateral disease. Amoxicillin is the most recommended first-line antibiotic agent. In penicillin-allergic patients, the use of a macrolide (erythromycin or azithromycin) has the greatest support. Nine of the 11 guidelines give a clear upper time limit of 72 hours for symptom improvement or resolution. Patients not improving on analgesia alone should be prescribed amoxicillin or a macrolide if penicillin-allergic, without the need for further clinical review. Failure to respond or worsening features after 72 hours of analgesia and first-line antibiotic therapy should prompt clinical review to reaffirm the diagnosis, exclude complications and switch to second-line treatment with amoxicillin-clavulanate.[3,16,26,33,39,43] Cefuroxime is the only second-line agent for the penicillin-allergic proposed by more than one guideline. Nine of the 11 guidelines recommend a 5-day course of initial antibiotic treatment in patients aged two years or older; six of the guidelines also recommend this course for patients aged six months to two years. There is no predominant opinion on the duration of antibiotic treatment for children aged six months or younger. Failure to respond after 10 days of antibiotics should be managed as outlined for second-line antibiotic failures (see the following section).

## Tympanocentesis

The French Health Products Safety Agency (French) guidelines advocate tympanocentesis by an otolaryngology specialist for children who are in severe pain and who have a bulging tympanic membrane.[19] As the natural history of acute otitis media often involves progression to spontaneous tympanic membrane perforation, tympanocentesis could be viewed as hastening a natural outcome that often relieves pain. This recommendation in the French Health Products Safety Agency guidelines is not referenced. In the American Academy of Family Physicians and American Academy of Pediatrics guidelines and the NICE guidelines, there is no mention of tympanocentesis or myringotomy for treatment. Kaleida *et al.* conducted a randomised, controlled trial of severe acute otitis media treatment involving 536 children, comparing myringotomy (with or without antibiotics) to amoxicillin or placebo, and found the former to have no advantage.[55] However, several guidelines recommend tympanocentesis as a diagnostic procedure in cases of acute otitis media unresponsive to second- or third-line antibiotic therapy.[3,16,19,26,39] The high degree of skill required to safely perform tympanocentesis can usually only be attained and maintained by specialist otolaryngological training and practice.[56] Whilst Pichichero advocates that general practitioners undertake tympanocentesis in their surgeries, this view is widely opposed because of the risks and logistical demands.[56,57] In routine UK specialist otolaryngological practice, tympanocentesis is rarely undertaken to guide antibiotic treatment. It is unclear whether this is a reflection of the high success rate of first-line intervention, or due to general practitioners' reluctance to pursue specialist referral for patients with acute otitis media which is hard to manage.

## Referral

The Scottish Intercollegiate Guideline Network recommends otolaryngological referral of children with acute otitis media complicated by facial paralysis and mastoiditis, and of those with more than four episodes of acute otitis media in six months.[33] This is similar to the Dutch Artsennet guidelines, which advise referral of acute otitis media patients with suspected meningitis or mastoiditis to an ENT doctor or paediatrician.[32] The British Columbia guidelines recommend elective referral to an ENT specialist if there are three episodes in six months or four episodes in 12 months, or if there is persistent perforation present for over six weeks.[18] In the UK, early specialist referral for children with recurrent otitis media is currently being publicised to general practitioners,[58] based on the Cochrane review of the use of ventilation tubes in recurrent acute otitis media.[59]

## Tympanostomy tubes

Tympanostomy tubes (also known as ventilation tubes or grommets) reduce the incidence of recurrent acute otitis media in children.[59] It is difficult to determine the proportion of children who undergo tympanostomy tube placement for recurrent acute otitis media as opposed to otitis media with effusion (OME). The latter can develop following acute otitis media, and is the prime indication for tympanostomy tube insertion. It is possible that national differences in the first-line management of acute otitis media will lead to differences in the OME disease burden and in requirements

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to manage the same. This is supported by the findings that the Netherlands, which boasts the lowest antibiotic prescription rate for acute otitis media, has the highest tympanostomy tube insertion rate (20 per 1000 children) of all developed Western countries. On the other hand, the US, which historically has had high antibiotic prescribing rates, has a comparatively low tympanostomy tube insertion rate (nine per 1000 children). The UK, which also has high antibiotic prescription rates, has the lowest tympanostomy tube insertion rate of the developed world countries reported by Schilder *et al.*[60] The downward trend in antibiotic prescribing rates for acute otitis media in both the UK and the US over the last 15 years if unrelated to any real reduction in acute otitis media incidence, may have led to a concomitant increase in OME, tympanostomy tube insertion, and other complications and sequelae of untreated or partially treated acute otitis media. However, between 2000 and 2006 UK myringotomy rates decreased by 22 per cent.[61] The increase in admissions for mastoiditis and mastoidectomy in children four years or younger has been discussed above.[45] The reduction in myringotomies and antibiotic prescriptions for acute otitis media are together resulting in an increased prevalence of mastoiditis amongst young children in the UK.

## Conclusions

Accurate diagnosis is critical in clinical practice and research. Future acute otitis media trials should use the American Academy of Family Physicians and American Academy of Pediatrics diagnostic criteria.

Current level IA evidenced treatment guidelines recommend initial observation with symptomatic treatment in non-severe infections in healthy patients aged over two years. Assessment and treatment of pain is essential. When antibiotics are used, a five-day course of amoxicillin is the most recommended first-line therapy.

In the UK and USA, antibiotic prescriptions for upper respiratory tract infections that include acute otitis media have been decreasing; this is related to a long-term and persistent reduction in the number of patients presenting with these conditions, which predated the publication of the American Academy of Family Physicians and American Academy of Pediatrics guidelines and the 2008 UK NICE guidelines.[62–64] The additive effect of treatment guidelines on the reduction in antibiotic prescription rates is questionable in view of most healthcare practitioners' poor adherence to such guidelines.[65,66] This poor adherence may be partly explained by the following: (1) the fact that recommendations on antibiotic avoidance only apply to patients presenting with mild to moderate acute otitis media; (2) the evidence of clear benefit of antibiotics in severe cases and children under two years of age; and (3) the higher rate of mastoiditis in untreated cases.

The community prevalence of, and optimal analgesia for, acute otitis media require further investigation.

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**MAIN ARTICLE**

# The contribution of hearing to normal balance

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## Abstract

*Introduction*: Normal balance relies on three sensory inputs: vision, proprioception and the peripheral vestibular system. This study assessed hearing change and postural control in normal subjects.

*Materials and methods*: Postural control in 20 normal volunteers was assessed using a Nintendo Wii gaming console and balance board. Each subject was tested standing upright for 30 seconds in a clinic room and a soundproof room with their eyes open, eyes closed, whilst standing on and off foam, and with and without ear defenders.

*Results*: There was significantly more postural sway in the following subjects: those standing with their eyes closed *vs* those with eyes open (normal room, $p = 0.0002$; soundproof room, $p = 0.0164$); those standing on foam with eyes open *vs* those standing normally with eyes open (in both rooms; $p < 0.05$); those standing with eyes open in a soundproof room *vs* a normal room ($p = 0.0164$); and those standing on foam in a soundproof room with eyes open and wearing ear defenders *vs* those in the same circumstances but without ear defenders.

*Conclusion*: Our results suggest that this method provides a simple, inexpensive tool for assessing static postural control. Whilst it is recognised that visual input and proprioception play a central role in maintaining posture, our findings suggest that ambient sound and hearing may also have a significant influence.

**Key words:** Balance; Hearing; Gait; Posture; Vestibular Function Tests

## Introduction

Normal human balance is classically described as relying on three sensory inputs: vision, proprioception and the peripheral vestibular system. This sensory information is relayed centrally, where it is integrated and interpreted. The latter requires a comparison to be made between the new information and previously generated templates, with a mismatch between the two resulting in perceived symptoms of dizziness, unsteadiness or vertigo.

The principal functions of the vestibular system are postural control and gaze stabilisation. Postural control is achieved by means of the vestibulospinal reflex, which allows rapid correction of posture in response to head acceleration, and the righting reflex, which maintains head position in a horizontal plane irrespective of trunk position.[1] The vestibulo-ocular reflex, in contrast, provides image stabilisation during head movement.

An increase in postural sway is a recognised consequence of eye closure, and has also been demonstrated in individuals with visual acuity and visual field impairments.[2–4] Similarly, immediately after sustaining an acute peripheral vestibular deficit, subjects demonstrate marked unsteadiness and gaze abnormalities, including skew deviations and nystagmus. Static and dynamic postural control is also markedly affected by bilateral vestibular hypofunction and peripheral neuropathy.[5]

Although there have been few formal studies indicating that hearing contributes to normal balance function, anecdotal accounts suggest that hearing loss may contribute to unsteadiness.[6] We therefore undertook the current study to assess postural control in human subjects in normal and sound-limited environments.

## Materials and methods

### *Subjects*

Twenty-one normal-hearing volunteers aged between 23 and 44 years were recruited to this pilot study. All subjects were regarded as independent in their activities of daily living.

Individuals with a history of hearing loss, balance disorder or visual abnormality were excluded from the study. Those with proprioceptive loss or peripheral neuropathy were also excluded.

Informed consent was obtained from all subjects.

### *Instrumentation*

Postural control was assessed using the Physio Fun software program (Nintendo, Kyoto, Japan), a Nintendo

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Wii™ gaming console and a balance board. The balance board contained multiple pressure sensors which measured the subject's centre of balance, and was calibrated using the subject's height (in cm) and weight (in kg). Sway measurements were recorded as an area of ellipse (measured in $cm^2$) depicting the centre of gravity (Figure 1a).

*Design*

Each subject was randomly assigned to one of two environments – a normal clinic room or a standard soundproof audiology booth (both of similar dimensions) – and then retested in the second environment.

Each subject was tested for 30 seconds, standing upright on the Wii balance board (Figure 1b), in one of the eight standing test scenarios (Table I). Serial measurements were taken, firstly with the subject standing barefoot on the Wii balance board with their eyes open and then closed, then repeated with the subject wearing industrial ear defenders and standing on foam, and then again with the subject standing on foam and the Wii board with ear defenders. Normal room and soundproof room sway measurements were recorded for each test scenario. The area of ellipse (indicating the centre of gravity) was recorded.

Data were statistically compared using the Friedman one analysis of variance test. A $p$ value of less than 0.05 was taken to indicate statistical significance.

## Results

*Normal room*

During testing in the normal clinic room, a significant increase in postural sway measurements was found for the following subjects: those standing with their eyes closed, compared with those with their eyes open ($p = 0.0002$); those standing on versus off foam ($p = 0.0164$); and those standing on foam with eyes open whilst wearing ear defenders versus standing on foam with eyes open and without ear defenders ($p = 0.0495$) (Table II).

*Soundproof room*

Table III shows the results for comparison of postural sway in the soundproof room. A significant increase in postural sway was found for the following subjects: those with their eyes open versus closed ($p = 0.0164$); those with eyes open standing on versus off foam ($p = 0.0495$); and those with eyes closed with versus without ear defenders, both on and off foam ($p = 0.0495$).

*Comparison of both rooms*

Table IV compares postural sway results from both rooms. There was a general trend towards increased sway for all standing test scenarios conducted in the soundproof room, compared with the normal room; however, a statistically significant difference was

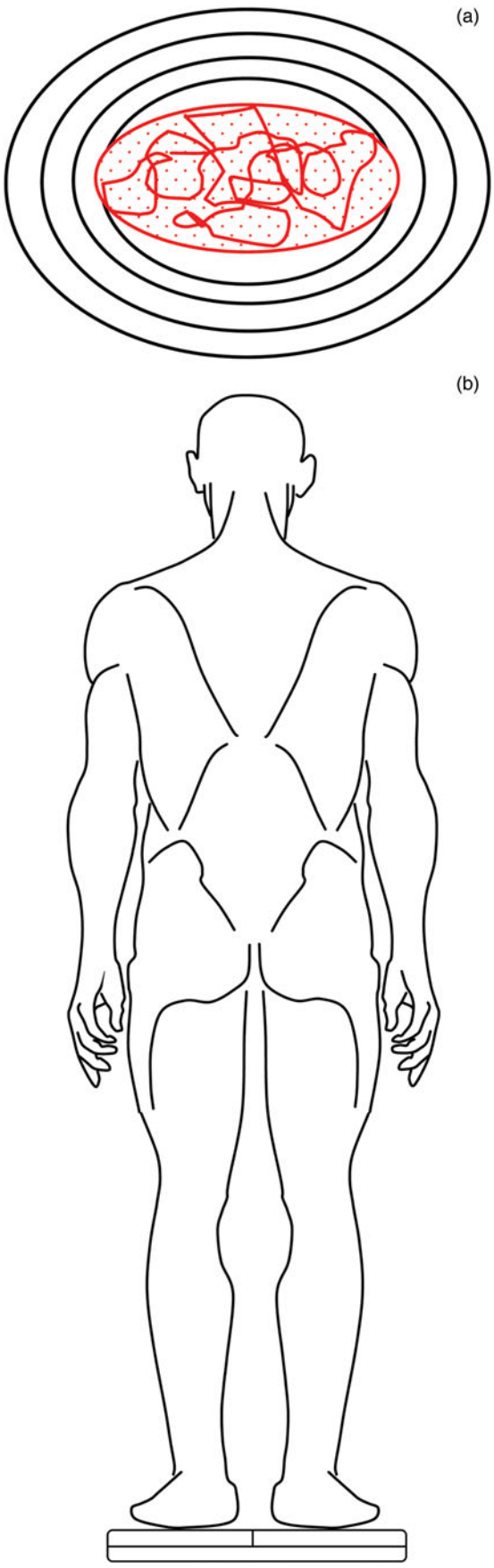


FIG. 1
(a) Graphical representation of the Wii output data for centre of gravity area. (b) Diagram of subject standing in the Romberg position on the balance platform.

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TABLE I
STANDING TEST SCENARIOS

| |
|---|
| Eyes open |
| Eyes closed |
| Eyes open + standing on foam |
| Eyes closed + standing on foam |
| Eyes open + ear defenders |
| Eyes closed + ear defenders |
| Eyes open + ear defenders + standing on foam |
| Eyes closed + ear defenders + standing on foam |

observed only between subjects standing with their eyes open ($p = 0.0164$).

## Discussion

It is currently believed that integration and interpretation of three primary sensory modalities are required to maintain balance, namely vision, proprioception and peripheral vestibular sensation. Our current model suggests that the new sensory information is compared with previously generated templates. An absence of a suitable template, or the inability to compare relayed information with those templates, results in perceived symptoms of dizziness, unsteadiness or vertigo.

Some studies have attempted to demonstrate the existence of additional sensory contributions to balance, including tactile sensations, as well as the effect of simultaneous performance of concentrative tasks.[7,8] Anecdotal accounts suggest that hearing loss may contribute to unsteadiness (e.g. 'clumsiness' in children with bilateral middle-ear effusions, and loss of balance in patients with unilateral or bilateral hypofunction when in the shower); however, no formal studies have demonstrated a clear relationship between auditory information and static postural control.[6]

Our study findings support the importance of visual and proprioceptive input with regards to normal balance. However, our results also suggest that auditory cues are important in maintaining postural control, as standing test scenarios with reduced auditory input (i.e. wearing ear defenders) or reduced ambient environmental sound (i.e. the soundproof room) resulted in increased postural sway. Whilst the audiology booth used in our study provided a sound-limited environment (i.e. a semi-anechoic chamber), some low-level ambient sound was produced by the hardware used during the study. However, the ear defenders worn by our subjects further limited hearing, and resulted in significantly greater sway in some scenarios.

As the basis of normal postural control relies on cross-referencing new sensory information against pre-existing central templates, we would suggest that normal balance templates include auditory information and that a reduction in ambient environmental sound, or hearing loss, significantly affects postural control. As our cohort was unlikely to routinely use ear defenders, nor to spend significant periods of time in a soundproof environment, these situations did not conform to any previously generated templates, and hence resulted in increased postural sway.

Interestingly, many patients undergoing audiological testing describe the environment as 'strange' or 'weird'. None of our subjects were audiology staff, who may have pre-generated templates for such an environment, and it would be interesting to assess this specific group in the future. It may be the case that the relative weighting of the different sensory

TABLE II
POSTURAL SWAY IN NORMAL ROOM: STATISTICAL COMPARISON

| Comparison | Friedman's statistic | *p* |
|---|---|---|
| Eyes open *vs* closed | 13.7619 | 0.0002 |
| Eyes open *vs* eyes open with ear defenders | 0.4286 | 0.5127 |
| Eyes open *vs* eyes open on foam | 5.7619 | 0.0164 |
| Eyes open *vs* eyes open on foam with ear defenders | 3.8571 | 0.0495 |
| Eyes closed *vs* eyes closed with ear defenders | 0.0476 | 0.8273 |
| Eyes closed *vs* eyes closed on foam | 0.4286 | 0.5127 |
| Eyes closed on foam *vs* eyes closed on foam with ear defenders | 1.1905 | 0.2752 |

TABLE III
POSTURAL SWAY IN SOUNDPROOF ROOM: STATISTICAL COMPARISON

| Comparison | Friedman's statistic | *p* |
|---|---|---|
| Eyes open *vs* eyes closed | 5.7619 | 0.0164 |
| Eyes open *vs* eyes open with ear defenders | 0.0476 | 0.8273 |
| Eyes open *vs* eyes open on foam | 3.8571 | 0.0495 |
| Eyes open vs eyes open on foam with ear defenders | 5.7619 | 0.0164 |
| Eyes closed *vs* eyes closed with ear defenders | 0.0476 | 0.8273 |
| Eyes closed *vs* eyes closed on foam | 0.4286 | 0.5127 |
| Eyes closed on foam *vs* eyes closed on foam with ear defenders | 3.8571 | 0.0495 |

TABLE IV
POSTURAL SWAY IN NORMAL *VS* SOUNDPROOF ROOM: STATISTICAL COMPARISON

| Scenario | Friedman's statistic | *p* |
|---|---|---|
| Eyes open | 5.7619 | 0.0164 |
| Eyes closed | 0.0476 | 0.8273 |
| Eyes open with ear defenders | 0.4286 | 0.5127 |
| Eyes open on foam with ear defenders | 0.4286 | 0.5127 |
| Eyes closed on foam | 0.4286 | 0.5127 |
| Eyes closed with ear defenders | 1.1905 | 0.2752 |
| Eyes closed on foam with ear defenders | 0.0476 | 0.8273 |
| Eyes open on foam | 0.4286 | 0.5217 |

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inputs for balance varies depending on one's environment, and that this weighting is determined by experience. Era and Heikkinen, for example, found poor postural control in subjects exposed to noise at work, and questioned the contribution of hearing to normal balance.[9] Moving auditory stimuli have also been shown to affect postural control.[10]

Auditory biofeedback has been suggested to have an effect on reducing body sway in individuals with bilateral vestibular loss. Tanaka *et al.* suggested that an auditory feedback system can be helpful for individuals with poor balance secondary to hearing impairment.[11] Patients with profound, bilateral loss of vestibular function have been shown to rely upon other sensory information to compensate.[1] However, Palm *et al.* found that exposure to non-specific auditory stimuli did not significantly affect postural stability.[3] These authors used auditory stimulation in the form of music played through headphones. They concluded that auditory stimuli may play a substantial role when one of the three main sensory modalities is impaired. The results of our study may support their suggestion.

The higher risk of falls in elderly individuals is attributed in large degree to the reduced visual acuity that occurs with ageing.[11] It has been suggested that elderly patients rely more on tactile input to maintain posture.[12] Tanaka *et al.* have suggested that reliable sensory information, especially during times of otherwise conflicting sensory input within changing environments, is crucial if falls are to be avoided.[12] Prado *et al.* found that 24 subjects performing dual tasks on a force plate had a reduced centre of balance, compared with subjects performing no tasks at all.[8] The results of the present study suggest that hearing should be optimised to promote balance; furthermore, our findings suggest that further study comparing postural sway in those with unilateral versus bilateral hearing aids would be useful.

- **Balance is proven to rely upon vision, proprioception and peripheral vestibular input**
- **Sensory inputs are processed centrally, and determine gaze stability and postural control**
- **Anecdotal accounts suggest hearing loss contributes to unsteadiness**
- **This study used a Nintendo Wii gaming console to assess postural control**
- **Balance was influenced by ambient noise levels**

Many methods have been used to measure postural sway, with varying success. The sensorimotor control of balance is a complex phenomenon, and each modality is not easily quantifiable by a single test. Kelso and Hellebrandt devised a footplate measuring the centre of foot pressure.[13] This method has been further developed with the use of an accelerometer mounted on a belt attached at the waist.[14] The Wii balance board utilises similar principles, and has recently been validated as an instrument to precisely quantify the centre of balance pressure. Its validity has been tested against the 'gold standard' force platform, with reliable results, making it a useful tool in the clinical setting.[15] Posturography was not feasible in the current study, due to logistical and measurement problems associated with its use in both a normal room and a soundproof room. Our results suggest that using the Wii gaming console provides a simple and inexpensive tool for assessing static postural control.

## Conclusion

The results of this pilot study suggest that auditory cues influence postural sway, and support anecdotal evidence of an association between hearing and balance. Clinical implications may include optimising patients' hearing in order to improve their global balance function.

Further study will be required to evaluate the reliability of this hypothesis. Additional research is required to assess postural sway in those with hearing loss (acute and chronic) and those with vestibular pathology.

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