

1 **Internet-based interventions for adults with hearing loss, tinnitus, and**
2 **vestibular disorders: a systematic review and meta-analysis**

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8 9 **Abstract**

10 Internet-based interventions have been developed to improve access to audio-vestibular
11 healthcare. This review aimed to identify outcomes of Internet interventions for adults with
12 hearing loss, tinnitus, and/or vestibular disorders. Electronic databases and manual searches were
13 performed to identify studies meeting eligibility for inclusion. Fifteen studies (1,811 participants)
14 met the inclusion criteria, with nine studies targeting tinnitus distress, five considering hearing
15 loss and one for vestibular difficulties. Only the tinnitus and hearing loss Internet intervention
16 studies were eligible for data synthesis. Internet-based interventions for hearing loss were
17 diverse. Overall they showed no significant effects, although a statistically significant moderate
18 effect ($d = 0.59$) was found after removing the study with the highest risk of bias (as a result of
19 high attrition). Most Internet-based interventions for tinnitus provided cognitive behavioural
20 therapy. They yielded statistically significant mean effect sizes for reducing tinnitus distress
21 compared with both inactive ($d = 0.59$) and active controls ($d = 0.32$). Significant effects were
22 also present for the secondary outcomes of anxiety, depression, insomnia, and quality of life

1 (combined effect $d = 0.28$). Only Internet-based interventions for tinnitus evaluated the 1-year
2 post-intervention effects indicated that results were maintained long-term ($d = 0.45$). Scientific
3 study quality was appraised using the GRADE approach and found to vary from very low to
4 moderate. This review indicates the potential of Internet interventions for tinnitus to provide
5 evidence-based accessible care. There is a need for additional high-quality evidence before
6 conclusive results can be established regarding the effects of audio-vestibular Internet
7 interventions.

8 *Systematic review registration:* PROSPERO CRD42018094801.

9

10 **Key Words**

11 Internet interventions; Hearing loss; Tinnitus; Vestibular disorders; Systematic review

12

13 **Abbreviations**

14 AMED: Allied and Complementary Medicine

15 CBT: Cognitive Behavioral Therapy

16 CINAHL: Cumulative Index to Nursing and Allied Health Literature

17 F2F: Face to Face

18 HA: Hearing aid

19 HADS: Hospital Anxiety and Depression Scale;

20 HHIE: Hearing Handicap Inventory for the elderly

21 HHQ: Hearing Handicap Questionnaire

22 IACT: Internet-based Acceptance and commitment therapy

- 1 IAT: Internet-based auditory training
- 2 IAR: Internet-based aural rehabilitation
- 3 ICBT: Internet-based cognitive behavioral therapy
- 4 IPC: Internet-based pre-fitting counseling
- 5 IQR: Interquartile range
- 6 IVR: Internet-based vestibular rehabilitation; F: Female; GAD-7: Generalized Anxiety Disorder;
- 7 PHQ-9: Patient health questionnaire
- 8 PRISMA: Preferred Reporting Items for Systematic reviews and Meta-analyses
- 9 PROSPERO: Prospective Register of Systematic Reviews
- 10 QOLI: Quality of life Inventory
- 11 RCT: Randomized Controlled Trial
- 12 SWLS: Satisfaction with life scales
- 13 TFI: Tinnitus Functional Index; UK: United Kingdom; USA: United States of America
- 14 VSS-SF: Vertigo Symptom Scale-Short Form

15

16 **Introduction**

17 Healthcare provision aims to ensure clinically and cost-effective treatments are provided
18 (Greenhalgh, 2017). Delivery of high-quality evidence-based healthcare is challenged by factors
19 such limited finances, enough healthcare workers, work pressures, and a lack of resources
20 (Hignett et al., 2018). Evidence-based healthcare is also hampered by a research-to-policy gap,
21 attributed to the low uptake of new interventions (Cairney & Oliver, 2017). Barriers associated
22 with this disparity include lack of timely research outputs and research methodological
23 shortcomings (Oliver, Innvar, Lorenc, Woodman, & Thomas, 2014). Moreover, healthcare

1 service delivery models have recently evolved from being more practitioner-centered to patient-
2 centered, placing emphasis on patient engagement and shared decision making (Richards,
3 Montori, Godlee, Lapsley, & Paul, 2013). The greater use of digital technologies is an example
4 of an attempt to overcome treatment barriers related to pressures on current healthcare systems
5 (Lupton, 2013).

6
7 Internet interventions are emerging as a means to provide affordable and accessible healthcare to
8 promote self-management and engagement (Andersson, 2018). An Internet-based intervention is
9 primarily a self-guided prescriptive program operated through a website. The intervention
10 attempts to create positive change, improve knowledge and understanding of health-related
11 conditions through the use of interactive web-based components (Barak, Klein, & Proudfoot,
12 2009). The information is generally divided into different modules with a set timeframe for
13 completion. Some Internet-based interventions are provided together with professional support
14 (guided), whereas others do not offer the support (unguided). Guidance can be synchronized (e.g.
15 real-time chats), asynchronized (e.g. not occurring at the same time such as when using e-mail)
16 or using a blended approach by combining various approaches.

17
18 Internet interventions have been developed within the field of audio-vestibular healthcare. This
19 includes rehabilitation programs for those with hearing loss (Malmberg, Lunner, Kähäri,
20 Jansson, & Andersson, 2015) tinnitus (Andersson & Kaldo, 2004) and vestibular rehabilitation
21 (Geraghty et al., 2017). Although individual studies have been conducted, knowledge of the
22 overall efficacy and effectiveness of Internet interventions for audio-vestibular healthcare is
23 required. A broad-spectrum systematic review focusing on identifying telehealth applications in

1 audiology, including screening, diagnostic and intervention applications was published in 2010
2 (Swanepoel & Hall, 2010). In this review, seven telehealth intervention studies were identified
3 that related to hearing aid fitting, cochlear implant programming, tinnitus therapy, and hearing
4 aid counseling. The Swanepoel & Hall review included all study designs and was not limited to
5 higher quality randomized controlled trial designs. Since this review, additional studies of
6 Internet interventions related to hearing loss rehabilitation and vestibular rehabilitation have been
7 published. Therefore, an updated review with a focus specifically on audio-vestibular Internet-
8 based interventions evaluated with higher levels of evidence (randomized controlled trials:
9 RCTs) is warranted.

10

11 Other intervention-related systematic reviews do exist. They have, however, not been specific to
12 Internet interventions for auditory disorders, but have focused on wider applications. These
13 include the use of eHealth for hearing aids, such as offline, mobile-based applications and
14 Internet-based platforms (Paglialonga, Nielsen, Ingo, Barr, & Laplante-Lévesque, 2018) and
15 tele-audiology for the rehabilitation of hearing impaired adults using hearing aids (Tao et al.,
16 2018). Moreover, no review specific to Internet-based interventions for tinnitus was found,
17 although an overview was provided of Internet-based tinnitus trials performed prior to 2015
18 (Andersson, 2015). Existing reviews on vestibular rehabilitation (Kundakci, Sultana, Taylor, &
19 Alshehri, 2018; Martins e Silva et al., 2016; Ricci et al., 2010), have also not focused on
20 Internet-based vestibular rehabilitation.

21

22 Determining the effects of Internet-based interventions for audio-vestibular difficulties is
23 important in order to establish their efficacy and effectiveness prior to considering whether they

1 can be implemented in hearing healthcare systems. The aim of this review was to investigate the
2 outcomes of Internet interventions for adults with hearing loss, tinnitus, and vestibular disorders
3 with the following specific questions:

4 (i) What are the outcomes of Internet-based interventions in reducing hearing disability,
5 tinnitus distress, and vestibular difficulties in adults?

6 (ii) What are the outcomes of Internet-based interventions for adults regarding the
7 associated difficulties of anxiety, depression, insomnia, and quality of life?

8 (iii) Are the outcomes of Internet-based interventions for hearing disability, tinnitus and
9 vestibular disorders maintained 1-year post-intervention?

10

11 **Methods**

12 **Protocol and registration**

13 This systematic review was prospectively registered with the International Prospective Register
14 of Systematic Reviews (PROSPERO number CRD42018094801). The methods selected were
15 guided by the Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA)
16 (Moher, Liberati, Tetzlaff, Altman, & Prisma Group, 2009) (see Supplementary material file 1).
17 The protocol can be found at (Beukes, Manchaiah, Baguley, Allen, & Andersson, 2018c).

18

19 **Eligibility Criteria**

20 The eligibility criteria were selected to address the research questions with reference to
21 Participants, Intervention, Comparators, Outcomes, Timings and Study designs (PICOTS)
22 (Schardt, Adams, Owens, Keitz, & Fontelo, 2007; University of York. Centre for Reviews and
23 Dissemination, 2009) as shown in Table 1. The criteria included English-language publications

1 with no date restrictions of manuscripts published or accepted for publication in peer-reviewed
2 academic journals.

3 **[Insert Table 1 around here]**

4
5 **Information sources**

6 A systematic search was undertaken between June and July 2018 and again between October and
7 November 2018 by the first author and an independent research assistant. This included the
8 following electronic research databases: EBSCOhost including Allied and Complementary
9 Medicine (AMED) and Cumulative Index to Nursing and Allied Health Literature (CINAHL),
10 PubMed (Including MEDLINE), Embase, and the Cochrane Central Register of Controlled
11 Trials database. Manual searches comprised of trial registers at clinical.gov and Cochrane Ear,
12 Nose and Throat Disorders Group Trials Register, hand-searching key journals and the reference
13 lists from the included studies, grey literature in google scholar and contacting stakeholders and
14 research experts in the field.

15
16 ***Search Strategy***

17 A peer-reviewed search strategy was used using medical subject headings (MeSH) terms to
18 target four key domains: (i) condition (e.g., hearing loss, tinnitus, and vestibular disorders); (ii)
19 intervention (e.g., intervention, treatment, therapy, program, strategy, self-help, rehabilitation);
20 (iii) mode of delivery (e.g., Internet, online, web-based); and study designs (randomized) was
21 developed together with an information specialist at Anglia Ruskin University. The use of search
22 terms and its Boolean combinations were adapted for each search engine to suit its requirements.

1 Supplementary material file 2 provides an example of the MEDLINE search strategy that was
2 used to search titles and abstracts and the number of records returned.

3

4 **Study selection**

5 Two authors (EB & VM) independently screened the studies to identify which met the inclusion
6 criteria by viewing the abstracts. The full texts of the identified studies were subsequently read to
7 determine eligibility. Inter-reviewer agreement using Cohen's Kappa was .84 (SD: 0.04),
8 indicating strong agreement (Kappa of .80–.90) (Cohen, 1960). Disparities were resolved
9 through discussion with a third reviewer (GA).

10

11 **Data collection process**

12 Data from included studies were recorded on data extraction forms using the PICOTS format
13 (University of York. Centre for Reviews and Dissemination, 2009). Data were extracted by EB
14 and verified by VM. The completed extraction forms were provided to all the authors for cross-
15 checking. Where data were missing or unclear from the published studies, the publication
16 authors were contacted. All authors responded and provided clarification.

17

18 **Data items**

19 The Cochrane data collection form for intervention studies with a randomized controlled trial
20 format was used to develop the extraction forms. The forms were tailored for the research
21 questions of this review. The form was piloted by EB and verified by VM. If both intention-to-
22 treat and per-protocol data were presented, the intention-to-treat estimation was used. The data
23 variables collected can be found in Supplementary material file 3.

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Risk of bias in individual studies

The risk of bias for the included studies was assessed using the Cochrane Collaboration’s tool (RoB 2) for randomized trials (Higgins et al., 2016). Included studies were assessed for bias across the following five domains: (1) bias arising from the randomization process; (2) bias due to deviations from intended interventions; (3) bias due to missing outcome data; (4) bias in measurement of the outcome; (5) bias in selection of the reported results. Each item was judged as yes, probably yes, probably no, no and no information by two reviewers (EB & VM). Any discrepancies were resolved by discussion and then by consulting with a third reviewer (GA). An overall risk of bias judgment was made as low risk of bias, some concerns or a high risk of bias for each domain.

Summary measures

Studies with more than one active treatment arm were aggregated and analyzed separately. The characteristics of the included studies were summarized according to the characteristics of the Participants, Interventions, Comparators, Outcomes, Timings and Study Design. The standardized mean difference (Cohen’s *d* effect size) were used as different scales of measurements were used to measure the same outcome. A positive effect size indicated that the Internet intervention group achieved better outcomes than the control group. Forest plots were constructed to visualize the effect sizes, confidence intervals and heterogeneous nature of the included studies (Egger, Davey Smith, Schneider, & Minder, 1997).

1 **Synthesis of results**

2 The meta-analysis was performed using Comprehensive Meta-Analysis software version 3 using
3 the random effects model (Borenstein, Rothstein, & Cohen, 2005). A quantitative synthesis was
4 included following considering whether it was possible to combine the individual studies
5 included in the systematic review. This included a power analysis and assessment of
6 heterogeneity (Valentine, Pigott, & Rothstein, 2010). Power calculations based on the random-
7 effects model formula by Valentine et al. (2010) indicated that 8 studies with an average of 45
8 participants were required to have 80% power to detect a small effect size ($d = 0.30$) at $\alpha =$
9 0.05 with moderate heterogeneity. The following heterogeneity criteria were met: (1) included
10 studies addressed similar questions; (2) there was a low risk of reporting and publication bias (3)
11 consistent outcomes were reported between studies; (6) sensitivity analysis was performed where
12 heterogeneity was high.

13
14 Quantitative synthesis was used to determine the mean difference with a 95% confidence interval
15 for the pooled analysis for the included studies. The mean between-group post-intervention
16 scores (or mean change from baseline to follow-up for 1-year + outcomes) and standard
17 deviations were used for these calculations (Borenstein, 2009). Due to the paucity of control
18 groups during the ≥ 1 -year follow-up phase for the trials (often due to the control group later also
19 undertaking the Internet intervention), within group mean gain effects were calculated for those
20 who had undergone the treatment and had follow-up measures 1-year post-intervention. In the
21 case of repeated measures data, the correlation between pre-and follow-up assessment was
22 estimated at $r = 0.90$, based on the average test-retest reliability of the tinnitus-specific outcome
23 measures used by the individual studies. The standardized mean difference (Cohen's d effect

1 size) was used to pool data using different scales of measurements to measure the same outcome
2 using a random-effects model. A positive effect size indicated that the Internet intervention
3 group achieved better outcomes than the control group. Effect sizes of $d < 0.5$ represent a small
4 effect, $d \geq 0.5 \leq 0.8$ a medium effect and $d \geq 0.8$ a large effect size (Cohen, 1992).

5
6 Consistency between studies was explored using the Q -value and I^2 statistic values. The I^2
7 statistic results were broadly categorized on a range of 0–100% (25% low, 50% moderate and
8 75% high) as suggested by Higgins, Thompson, Deeks, & Altman, (2003). A p -value of < 0.1
9 was considered statistically significant. If substantial heterogeneity was identified this was
10 explored through the pre-specified subgroup analyzes and sensitivity analyzes, where sufficient
11 data permitted Tau^2 was used to measure variance.

12 13 **Risk of bias across studies**

14 Selective outcome reporting was applied by identifying whether there were any differences
15 between the protocols and the final study of eligible studies. Authors were contacted to obtain
16 additional information where required. Missing data were analyzed to determine whether it is
17 missing at random or not, to determine the most appropriate way of dealing with the missing data
18 (Shuster, 2011). Publication bias was explored using funnel plots. Orwin's fail-safe N procedure
19 was used to numerically identify bias. Duval and Tweedie's trim and fill iterative procedure were
20 used to remove the most extreme studies from the positive side of the funnel plot and re-compute
21 the effect size (Borenstein, Hedges, Higgins, & Rothstein, 2009).

22

1 **Additional analyses**

2 Where sufficient data were available data synthesis was performed for each Internet intervention
3 (hearing loss and tinnitus). Additional subgroup analyses were conducted for:

- 4 • *Outcomes*: primary and secondary (anxiety, depression, insomnia, quality of life) at post-
5 intervention
- 6 • *Long term effect*: 1-year post-intervention effects for the primary outcomes
- 7 • *Study designs*: separating those with inactive and active comparators.

8

9 A sensitivity analysis was conducted by excluding those studies with a high risk of bias, thereby
10 determining the robustness of the conclusions from the included studies. Assessing how
11 outcomes of studies from specific (collaborating) research groups influence the summary effect
12 size was also undertaken.

13

14 **Confidence in the cumulative estimate**

15 Judgments about the quality of the evidence for each research question were rated according to
16 the Grading of Recommendations Assessment, Development and Evaluation (GRADE) protocol
17 (Balshem et al., 2011). The level of evidence was scored to be either high quality, moderate
18 quality, low quality or very low quality. These judgments were made independently by two
19 reviewers (EB, VM). The lower the score the less confidence in the effect estimate, the higher
20 the score, the more confidence there is that the true effect lies close to that of the estimate of the
21 effect.

22

1 **Results**

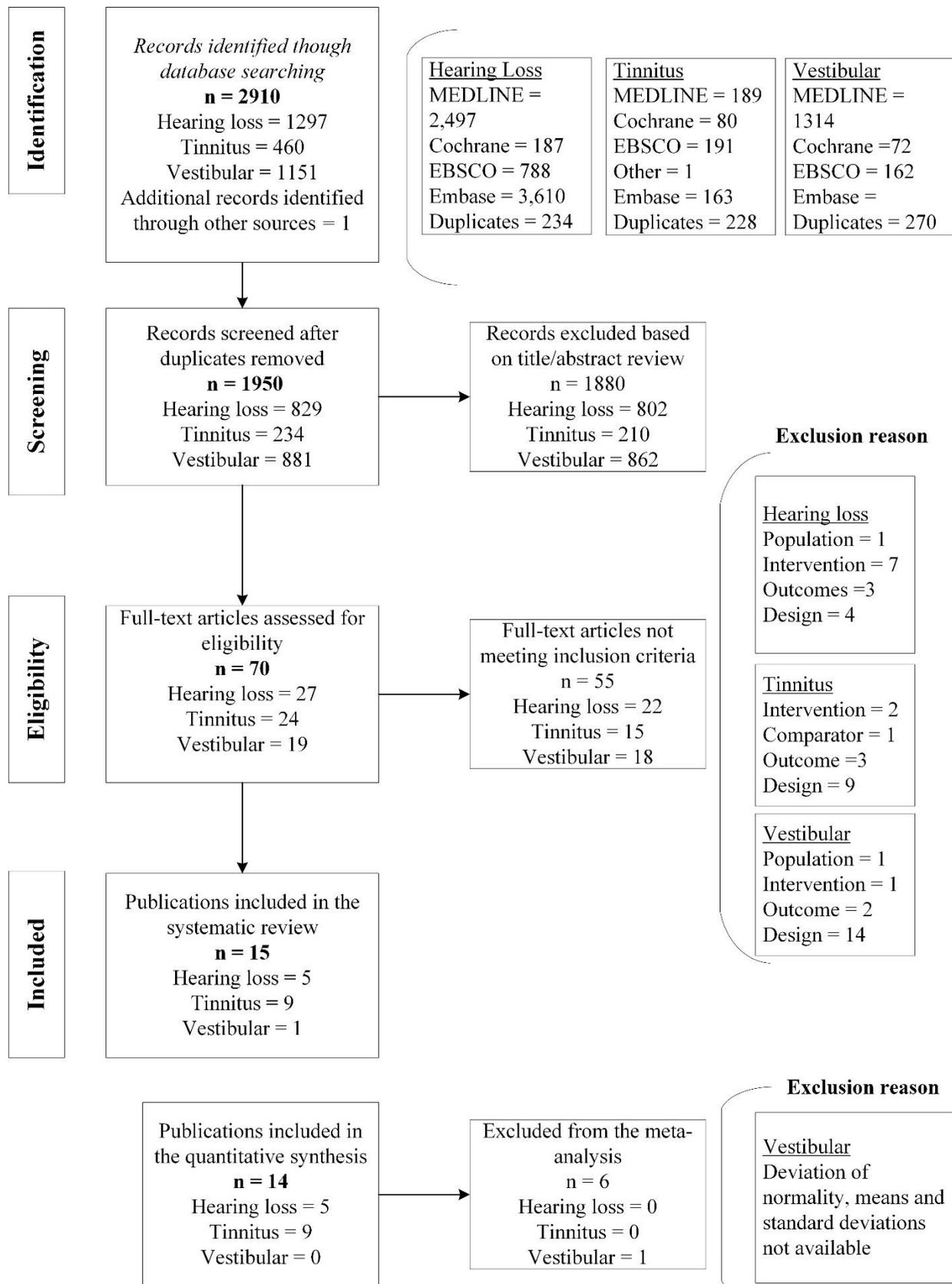
2 **Study selection**

3 Figure 1 shows the search results and included studies. Following determination of eligibility, 15
4 studies, with 1,811 adult participants were included. Of these, five were hearing loss Internet
5 interventions [350 participants], four were 2-arm efficacy trials with inactive controls
6 (Manchaiah, Rönnerberg, Andersson, & Lunner, 2014; Molander et al., 2018; Thorén, Svensson,
7 Törnqvist, Carlbring, & Lunner, 2011; Thorén, Öberg, Wänström, Andersson, & Lunner, 2014)
8 and one was a 2-arm effectiveness trial using an active control (Malmberg et al., 2018).

9 There were nine Internet interventions for tinnitus included [1,165 participants]. Eight
10 were 2 to 4 arm efficacy trials using a mixture of inactive and active controls (Andersson,
11 Stromgren, Strom, & Lyttkens, 2002; Beukes, Baguley, Allen, Manchaiah, & Andersson, 2017;
12 Hesser et al., 2012b; Jasper et al., 2014; Kaldo et al., 2008; Nyenhuis, Zastrutzki, Jäger, &
13 Kröner-Herwig, 2013; Weise, Kleinstauber, & Andersson, 2016) of which one reported only
14 long-term results (Beukes, Allen, & Baguley, Manchaiah, Andersson, 2018b) and one was an
15 effectiveness trial (Beukes, Andersson, Allen, Manchaiah, and Baguley, 2018a).

16 Only one Internet-based intervention 2-arm effectiveness trial for vestibular rehabilitation
17 met the inclusion criteria (Geraghty et al., 2017). Potential studies were most often excluded due
18 to not fulfilling the criteria of being randomized or the intervention not being sufficiently
19 Internet-based. A summary of the studies excluded is provided in Supplementary material file 4.

20



1 **Figure 1:** Flowchart of identified and included studies

2

3 **Study characteristics**

4 The characteristics of the studies are presented in Table 2. The mean population age was 56
5 years (SD: 11.7), with those undertaking hearing loss and vestibular Internet interventions being
6 older than those undertaking the tinnitus Internet interventions. The vestibular intervention
7 specifically targeted older adults. There were no Internet-based interventions included that
8 targeted younger adults or military veteran populations. The majority of participants for the
9 hearing loss and tinnitus interventions were male at 52% and 55% respectively. This trend was
10 reversed for the vestibular Internet intervention, which had a greater percentage of female
11 participants at 66%. The greatest number of studies originated in Sweden, followed by the UK
12 and then Germany. There were approximately 53–57 participants in each treatment arm (range
13 35–160), with fewer participants overall for the hearing loss interventions (35 in each treatment
14 arm). Attrition rates (range 4–75%) were lowest for the tinnitus interventions (mean 14%) and
15 highest for the hearing loss interventions (mean 32%). The highest attrition rate, at 75%, was
16 from a published failed clinical trial for a hearing loss Internet Intervention (Manchaiah et al.,
17 2014). Most trial designs were efficacy trials using a range of Interventions and comparators.
18 The majority of the inactive controls were online discussion forums or waiting list controls.
19 Active controls included group-based CBT, bibliotherapy, or individualized face-to-face care.

20 The majority of the hearing loss interventions focused on aural rehabilitation. One was
21 aimed at pre-hearing aid counseling (Manchaiah et al., 2014), one aimed to address associated
22 psychological distress using acceptance and commitment therapy (Molander et al., 2018), one
23 was for recent hearing aid users (Malmberg, Lunner, Kahari, & Andersson, 2017) and two for

1 experienced hearing aid users (Thorén, Svensson, Törnqvist, Carlbring, & Lunner, 2011; Thorén
2 et al., 2014). There was one effectiveness trial (Malmberg et al., 2017).

3 Most of the tinnitus interventions were cognitive behavioral therapy (CBT) and only one
4 study included a treatment arm providing acceptance and commitment therapy (Hesser et al.,
5 2012b). There was only one effectiveness trial meeting the inclusion criteria (Beukes et al.,
6 2018a).

7 The vestibular Internet intervention was vestibular rehabilitation for adults aged 50 years
8 or older experiencing motion-provoked dizziness in primary care (Geraghty et al., 2017). A
9 multi-center effectiveness trial was undertaken comparing the Internet intervention with usual
10 care. Results indicated that the Internet group had less self-reported dizziness and dizziness-
11 related disability at 3 and 6 months post-intervention compared with the usual care group. There
12 was a greater reduction in anxiety at 3 months, but not 6 months post-intervention for the
13 Internet group compared with the usual care group. There were no significant differences
14 between the groups with regards to depression.

15

16 **[Insert Table 2 around here]**

17 The outcome measures used are seen in Table 3. These focused on the primary outcome, anxiety
18 and depression, with fewer studies investigating insomnia, quality of life and long-term
19 outcomes. In terms of the outcome assessment measures selected, high methodological quality
20 was indicated when psychometrically validated disorder-specific questionnaires were used. All
21 studies included at least one secondary outcome measure. All the Internet intervention arms
22 provided guidance except for the vestibular rehabilitation Internet intervention.

23 **[Insert Table 3 around here]**

1 **Risk of bias within studies**

2 The estimated risk of bias for the included studies was assessed using the Cochrane
3 Collaboration's tool (RoB 2) for randomized trials (Figure 2). There were two studies (13%) that
4 had a high risk of bias (Andersson et al., 2002; Manchaiah et al., 2014). This was due to high
5 attrition rates in these studies leading to a risk of bias due to missing outcome data and possible
6 deviations from the intended interventions due to poor adherence. No bias in the selective
7 reporting of results was identified. Some concerns were identified regarding the measurement of
8 the outcome as it was not always clear whether the data analyst was blinded for group allocation.

9

10 **Figure 2:** Estimated risk of bias across all included studies

11

12 **Risk of bias across studies**

13 Inspection of the funnel plots and Duval and Tweedie's trim and fill procedure did not reveal any
14 major publication bias in any of the meta-analyses conducted. As a formal test of funnel plot
15 asymmetry, rank correlation testing indicated a non-statistically significant Kendall's tau rank
16 correlation test ($Tau = -0.07, p = 0.71$). The effect sizes adjustment for publication bias using the
17 trim-and-fill procedure was implemented and imputed for three studies to adjust the point
18 estimate from 0.40 to 0.32. Orwin's fail-safe indicated that 54 studies were required to bring the
19 effect size to > 0.1 .

20

21 **Synthesis of results**

22 Of the 15 studies meeting the inclusion criteria, 14 were suitable for quantitative data synthesis.
23 The study related to the vestibular Internet intervention (Geraghty et al., 2017) was excluded

1 from the data synthesis due to a deviation of normality in the data. Calculating means and
2 standard deviations from these data was not appropriate. There were 5 hearing loss Internet
3 interventions included (4 with inactive controls, 1 with an inactive control).

4 As multiple control groups were used by Nyenhuis, Zastrutzki, Weise, Jäger, & Kröner-
5 Herwig, (2013); Hesser et al., (2012a) and Jasper et al., (2014) this enabled four further
6 independent control groups to be used during data syntheses. In total there were 13 were tinnitus
7 Internet intervention comparisons (7 with inactive controls, 5 with active controls and 1 with
8 long-term data) as shown in Table 4. The two effectiveness trials (Beukes et al., 2018a;
9 Malmberg et al., 2017) were included as active controls as there were not sufficient effectiveness
10 studies for separate analyses.

11 **[Insert Table 4 around here]**

1 ($p < 0.001$) of tinnitus Internet-based interventions over both inactive control conditions of $d =$
2 0.61 (0.47 to 0.72) and active controls of $d = 0.35$ (0.18 to 0.52) was found (see Figure 4).
3 The choice of outcome measure did not alter these results when grouping studies using the
4 tinnitus questionnaires with similar constructs (e.g. removing those using the Tinnitus
5 Questionnaire which has more items).

6

7

[Insert Figure 4 around here]

1 **Additional analysis**

2 *Outcomes of hearing loss Internet-based interventions in reducing associated difficulties*

3 A small pooled effect size was found at $d = 0.21$ (0.05 to 0.37) for improving associated
4 difficulties, favoring the hearing loss Internet interventions over the control conditions (see
5 Figure 5 and Table 6). A small pooled between-group effect size for reducing depression using
6 hearing loss Internet interventions was found at $d = 0.29$ (0.05 to 0.30). This indicated a
7 significant favor over inactive controls at $d = 0.41$ (0.13 to 0.70) but no significant difference
8 was found when comparing to the active bibliotherapy control trial. In terms of reducing anxiety,
9 an equivalent finding between Internet interventions and the control groups was found both
10 overall and when comparing to either inactive or active controls. Only the active control trial
11 (Molander et al., 2018) assessed effect on quality of hearing loss and found a large effect at $d =$
12 0.88 (0.35 to 1.40) compared with the bibliotherapy control group.

13

14 **[Insert Figure 5 around here]**

15 **[Insert Table 6 around here]**

16

17 *Outcomes of tinnitus Internet-based interventions in reducing associated difficulties*

18 A small pooled effect size was found at $d = 0.29$ (0.21 to 0.36) for improving associated
19 difficulties, favoring the tinnitus Internet interventions over the control conditions (see Figure 6
20 and Table 6). Internet based interventions for tinnitus significantly reduced anxiety and
21 depression, indicating small effect sizes for these outcomes. This finding remained for studies
22 using inactive controls but was not significant when using active controls.

1 The pooled between-group effect size for reducing insomnia from Internet interventions for
2 tinnitus was $d = 0.42$ (0.27 to 0.57), indicating a significant favor of the Internet-based
3 interventions over both inactive ($d = 0.47$) and active ($d = 0.31$) control conditions. There was no
4 significant effect for quality of life.

5 **[Insert Figure 6 around here]**

6

1 *Outcomes of Internet-based interventions in reducing tinnitus distress 1 year post-intervention*
2 For the trials using pre-post data (inactive controls where the control group was not followed up
3 or also later undertook the Internet intervention), the overall within-group effect was small at $d =$
4 0.43 (0.27 to 0.59), and significant heterogeneity ($I^2 = 85\%$) was present. This finding remained
5 for studies using inactive controls and indicated equivalent results in one study using group-
6 based CBT as an active control.

8 **Discussion**

9 This review is the first to our knowledge evaluating the evidence base for Internet interventions
10 for audio-vestibular disorders. It investigated not only the primary effects but also the secondary
11 and long-term effects of such interventions. As auditory-vestibular disorders are often associated
12 with reduced quality of life, insomnia, anxiety and depression investigating whether the
13 interventions can improve these secondary effects was included in the review. The review
14 identified 15 studies meeting the reviews' inclusion criteria consisting of 1,811 adult
15 participants. The majority of studies were tinnitus Internet interventions (9 studies) based on
16 CBT, followed by 5 hearing loss Internet interventions (1 pre-fitting, 3 post-hearing aid fitting
17 and 1 for physiological distress) and 1 vestibular rehabilitation Internet intervention. Potential
18 studies were most frequently excluded as they did not fulfill the criteria of evaluating effects in a
19 randomized format (e.g. Kaldo-Sandström, Larsen, & Andersson, 2004; Pyykkö, Manchaiah,
20 Kentala, Levo, & Juhola, 2017) or the intervention provided was not sufficiently Internet-based
21 (e.g. Ferguson, Brandreth, Brassington, Leighton, & Wharrad, 2016). It is encouraging that more
22 applications of Internet-based interventions exist when considering all these additional study
23 designs (e.g. Paglialonga et al., 2018).

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The rest of the discussion focuses on the identified effects.

Summary of the outcomes of hearing loss Internet-based interventions

A variety of approaches were used to provide hearing rehabilitation at different stages of the patient pathway and to address different difficulties encountered. A pre-fitting intervention was one approach (Manchaiah et al., 2014) and aural rehabilitation for recently fitted (Malmberg et al., 2107) and experience hearing aid users (Thorén et al., 2011, 2014) were other approaches. There was also an intervention to address the associated psychological distress based on acceptance and commitment therapy (Molander et al., 2018). Drawing firm conclusions regarding these interventions is not possible due to the lack of power and high heterogeneity. No significant effect was found for Internet-based interventions, however, conducting a sensitivity analysis without the Manchaiah et al. (2014) study, which had high attrition, produced a significant moderate effect of $d = 0.59$ (0.29 to 0.90). These results indicate that although the evidence is not yet available, there are indications that Internet interventions for hearing loss can be of value and further high-quality studies in this field are indicated.

There are many challenges associated with developing these interventions due to the extensive professional input hearing loss rehabilitation requires. This input is also required at many stages of the patient journey. Moreover, Internet-based interventions may not be suitable for all types of interventions and populations, as some people, may not yet have come to terms with having a hearing loss. A state-of-the-art review regarding eHealth for adults with hearing aids found an increase in the development of eHealth resources for education and information regarding

1 hearing loss and hearing aids, screening and assessments, hearing rehabilitation and auditory and
2 cognitive training (Paglialonga et al., 2018).

3
4 A small pooled effect sized was found for improving secondary outcomes, favoring the hearing
5 loss Internet interventions over the control conditions. A small effect size for reducing
6 depression and equivalent finding between Internet interventions and the control groups for
7 reducing anxiety was found. Only the active control trial (Molander et al., 2018) assessed the
8 effect on quality of hearing loss and found a large effect compared with the bibliotherapy control
9 group.

10
11 Much previous research related to auditory rehabilitation has focused on hearing aid use and the
12 improvements these can bring to quality of life (Contrera et al., 2016), memory, depression and
13 cognitive status (Castiglione et al., 2016). When comparing those with and without long-term
14 hearing aids (n = 666) hearing aids were found to reduce hearing handicap and promote physical
15 health but not promote cognitive function, mental health and social engagement (Dawes et al.,
16 2014). The quality of auditory rehabilitation received in addition to the use of hearing aids may
17 be a key factor.

18
19 The use of evidence-based Internet-based rehabilitation may enable greater access to this
20 rehabilitation. Much work is still required to optimize Internet interventions to provide an
21 effective rehabilitation pathway for hearing loss. Reduced diversity regarding the use of outcome
22 measures and improvements in monitoring of the long-term effects will further build on the
23 knowledge base of auditory rehabilitation for hearing loss (Fiona et al., 2015). Incorporating

1 eHealth for some aspects of hearing rehabilitation has many service and cost advantages, even if
2 a blended approach is taken (Saunders, Brice, & Alimoradian, 2018). This may be an area where
3 involving service users in the development of these interventions is key (as done by Ferguson et
4 al., 2018). Working at overcoming present barriers and unifying intervention approaches to
5 improve the feasibility and efficiency of such interventions should be the focus of subsequent
6 research (Tao et al., 2018).

7

8 *Summary of the outcomes of tinnitus Internet-based interventions*

9 Overall, a more unified approach was present for Internet-based interventions for tinnitus in
10 comparison to those for hearing loss and vestibular rehabilitation. All the Internet tinnitus
11 interventions used CBT as the theoretical underpinning. A medium effect for tinnitus Internet-
12 based interventions was found ($d = 0.50$), which was slightly higher at $d = 0.59$ for inactive
13 controls than $d = 0.32$ for those with active control conditions.

14

15 The summary effects found for tinnitus Internet interventions were in line with those from a
16 systematic review regarding tinnitus management (Hoare, Kowalkowski, Kang, & Hall, 2011)
17 where an improvement was reported in 9 out of 10 trials comparing CBT for tinnitus (face-to-
18 face and online) versus non-CBT controls. The results of the present review are also similar to an
19 earlier systematic review finding a significant effect for CBT tinnitus interventions in
20 comparison with both inactive controls ($g = 0.70$) and active controls ($g = 0.55$) (Hesser, Weise,
21 Westin, & Andersson, 2011). The result of the present review are slightly better than those
22 reported in an earlier review by (Martinez-Devesa, Perera, Theodoulou, & Waddell, 2010) of $d =$
23 0.24 for inactive controls and $d = 0.10$ for active controls. A moderate overall effect size ($g =$

1 0.58) was also reported when reviewing Internet-based tinnitus interventions compared with
2 inactive controls with a smaller effect of $g = 0.13$ for those compared to active controls
3 (Andersson, 2015). When comparing guided Internet-based versus face-to-face CBT for
4 psychiatric and somatic disorders equivalent results were also found (Carlbring et al., 2018).
5
6 Similar to the hearing loss Internet interventions, a small pooled effect size was also found for
7 favoring tinnitus Internet interventions over control conditions for improving associated
8 difficulties. Internet-based interventions for tinnitus significantly reduced anxiety, depression
9 and insomnia. There was no significant effect for quality of life. This finding may partly relate to
10 the lack of appropriate quality of life measures for tinnitus, making valid measurements of this
11 aspect difficult.
12
13 Previous systematic reviews regarding CBT for tinnitus also reported small effect sizes that were
14 marginally higher at $g = 0.35$ for mood measures when combining anxiety and depression
15 measures (Hesser et al., 2011) and $d = 0.37$ for depression (Martinez-Devesa et al., 2010). In
16 contrast, a review of tinnitus management strategies reported that only two out of seven studies
17 found an improvement in depression and one out of three, an improvement in anxiety (Hoare et
18 al., 2011). The present review expanded on these reviews by considering secondary intervention
19 effects as well. Of interest was that a much larger effect on the sensation of wellbeing ($d = 0.91$)
20 was reported by Martinez-Devesa et al. (2010) for CBT tinnitus interventions, although this was
21 calculated from tinnitus outcome measures and not using quality of life assessment measures.
22 These results indicate that Internet interventions have potential to address associated difficulties

1 that accompany hearing-related problems. Ways of maximizing these improvements should be
2 sought (Donahue, Dubno, & Beck, 2010).

3
4 Overall results are maintained long-term (1-year post-intervention) for studies relating to tinnitus
5 Internet interventions that generally used within-group comparisons. The longest follow-up for
6 studies of Internet interventions for hearing loss and vestibular difficulties was 6 months. In a
7 previous review, the longer-term effects (3–18 months) of CBT tinnitus interventions were found
8 to be higher at $g = 0.60$, although effect sizes decreased slightly over time (Hesser et al., 2011).
9 More studies to evaluate the long-term outcomes of Internet interventions are required to monitor
10 these effects even longer term. Future studies should also examine the applications of Internet-
11 based interventions as a component in blended approaches, where Internet interventions are used
12 as one component of care.

13

14

15 *Summary of the outcomes of vestibular Internet-based interventions*

16 Only one vestibular rehabilitation Internet intervention met the inclusion criteria. This was for a
17 vestibular rehabilitation intervention for adults aged 50 years or older experiencing motion-
18 provoked dizziness in primary care (Geraghty et al., 2017). There was a greater reduction in
19 anxiety at 3 months, but not 6 months post-intervention for the Internet group and no significant
20 differences between the groups with regards to depression. Data synthesis of this intervention
21 was not possible and as only one study was identified, no clear conclusions can be drawn
22 regarding the effects of Internet interventions for vestibular difficulties.

23

1 An Internet-based self-help resource for patients with Ménière's disease was developed (Pyykkö
2 et al., 2017) but did not meet the inclusion criteria for this review. Previous systematic reviews
3 regarding the effectiveness of vestibular rehabilitation have found the benefits of these
4 interventions, although only a few studies ($n = 4-9$) have been included in these reviews
5 (Kundakci, Sultana, Taylor, & Alshehri, 2018; Martins e Silva et al., 2016; Ricci et al., 2010).
6 Even though these findings are encouraging, there is a clear need for further development of
7 interventions to assist with vestibular difficulties, especially considering the high prevalence of
8 these difficulties.

9

10 **Study Implications and Future Directions**

11 Internet interventions have the potential to improve accessibility and affordability of hearing
12 healthcare services and as a result have been the central focus of discussions about future hearing
13 healthcare delivery (Donahue et al., 2010). These interventions can be used as a replacement of
14 routine care in certain conditions such as tinnitus (e.g., Beukes et al., 2018a) or as supplementary
15 care in conditions such as hearing loss (e.g., Thorén et al., 2011, 2014; Malmberg et al., 2017).
16 Attrition rates were variable (4–75%) with an overall attrition rate of 20%. This is slightly higher
17 than the average dropout rate of 16% for Internet versus face-to-face CBT for psychiatric and
18 somatic disorders (Carlbring et al., 2018). Very similar drop-out rates were found when
19 comparing rates between those doing the Internet intervention and those in the active control
20 conditions such as group-based therapy as also reported in the systematic review by Carlbring et
21 al. (2018). Future Internet interventions should be mindful of incorporating strategies to improve
22 attrition rates. It is clear from this review that more studies are required, particularly to address
23 hearing loss and vestibular rehabilitation. Interesting, no Internet-interventions targeted the

1 combination of hearing loss, tinnitus or imbalance, yet often more than one audio-vestibular
2 condition is often found to occur in the same individual. To maximize outcomes of Internet
3 interventions, it is important that future interventions implement elements and approaches and
4 theoretical applications that are known to improve outcomes. Including a process evaluation can
5 assist in identifying factors that contribute to the outcomes obtained (Moore et al., 2015). To
6 date, there is only one example of a hearing-related Internet-based intervention including process
7 evaluation (Beukes, Manchaiah, Baguley, Allen & Andersson, 2018d). Moreover, studies are
8 needed to examine the cost-benefit and cost-utility analysis of Internet interventions for hearing-
9 related conditions. Reporting of adverse and unwanted effects of Internet interventions was not
10 prominent within the included studies. Presenting these data is important for future trials to be
11 able to review their effects more holistically.

12

13 **Limitations**

14 This synthesis should be interpreted with caution, bearing in mind that high-quality evidence is
15 not yet available for Internet interventions in the field of hearing disorders. Moreover, only
16 published studies were included, and although publication bias was not found. The studies included
17 were conducted in only three countries (Germany, Sweden, and the United Kingdom), making
18 wider generalizations difficult. Only six studies monitored the long-term effects. Search limitations
19 include that the inclusion criteria was limited to publications in English due to time and financial
20 constraints. Due to the limited number of high-quality interventions present, data synthesis for the
21 hearing loss interventions was slightly underpowered. Two studies with high risk of bias were
22 included which contributed to study heterogeneity which further affected data synthesis. When

1 further Internet interventions for tinnitus, hearing loss and vestibular disorders have been
2 developed and evaluated, reviews for each disorder in isolation are recommended.

3

4 **Conclusions**

5 The present review indicates a lack of enough high-quality evidence to draw firm conclusions,
6 although the potential of Internet interventions as a form of rehabilitation for auditory-vestibular
7 difficulties is clear. The results from this review need to be interpreted considering the quality of
8 the papers included, which ranged from very low to moderate quality evidence. Only two
9 effectiveness studies were present, indicating that more research is required to establish how
10 Internet interventions can be applied clinically and later implemented (Folker et al., 2018). This
11 review can be used as an indication of research needs in view of the later implementation of
12 these Internet interventions for audio-vestibular disorders.

13

14 **Ethical Approval and Consent to Participate**

15 Not applicable. Ethical approval is not required.

16

17 **Declaration of Conflicting Interests**

18 All authors views are their own and do not reflect those of their supporting institutions. David
19 Baguley is supported by the UK NIHR, but his opinions are his own and do not reflect those of
20 the NIHR or Department of Health and Social Care.

21

22 **Acknowledgments**

1 The information specialist, Andrea Packwood at Anglia Ruskin University and Vibhu Grover,
2 from Lamar University for assistance with the search strategy and systematic searches.

3

4 **Funding**

5 This research received no specific grant from any funding agency in the public, commercial, or
6 not-for-profit sectors.

7

8 **Authors' Contributions**

9 EB and VM conceptualized this study. All authors contributed to the design and provided input
10 across all sections. EB performed all data analysis and drafted the manuscript. All authors
11 approved the final version.

12

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4 **Supplemental Files**

5 **Supplementary material file 1:** PRISMA 2009 Checklist for reporting of systematic reviews

6 **Supplementary material file 2:** Search strategy for PubMed (MEDLINE) database

7 **Supplementary material file 3:** Data extraction forms

8 **Supplementary material file 4:** A summary of the excluded studies

9

10 **Table 1. Inclusion and exclusion criteria for the review**

11

	Inclusion	Exclusion
Participants	All adults (aged ≥ 18 years) from both clinical and non-clinical samples (with acute or chronic complaints of hearing loss, tinnitus and/or vestibular disorders)	Studies focusing on children or adolescents
Interventions	Guided and self-guided Internet-based interventions as a structured form of self-help aimed at reducing difficulties related to hearing loss, vestibular disorders, and tinnitus. Hearing aid fittings may be included as part of the treatment	Solely computer-based or app-based interventions. Interventions using a predominantly blended approach, isolated online discussion forums and Internet interventions running concurrently with additional treatments not related to hearing aid fittings
Comparators	Both inactive and active controls with no restrictions on the starting point of the interventions or their durations	No comparison groups (unless this is for long-term outcomes where control conditions may no longer be available), comparators comparing the role of guidance using the same Internet-based intervention in both the experimental and the control groups
Outcomes	Reporting results from a validated self-reported outcome measure related to the main difficulty	Primary outcome not a self-reported measure or not related to hearing loss, tinnitus or vestibular difficulties

	targeted e.g. hearing loss, tinnitus, or vestibular difficulties.	
Study designs	Randomized controlled trials (RCTs)	Cluster randomized RCTs, non-randomized trials, other non-RCT designs such as purely qualitative studies, repeated measures designs, unless this is for the long-term outcomes and control conditions are no longer available
Timings	At least two data points required for pre and post-intervention or follow-up	No post-intervention follow-up period

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1 **Table 2: Characteristics of the included studies**
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Characteristic	Overall	Hearing Loss	Tinnitus	Vestibular
Mean age (SD)	56.2 (11.7)	63.3 (11.4)	51.4 (12.1)	67.3 (9.0)
Gender				
Male (%)	47	52	55	34
Female (%)	53	48	45	66
Country				
Sweden	7	4	3	0
Germany	3	0	3	0
UK	5	1	3	1
Participants: Mean (SD)				
Internet-based				
interventions	56.7 (35.9)	35.0 (4.7)	57.3 (24.9)	160
Controls	53.3 (29.3)	35.0 (4.7)	52.9 (19.0)	136
Attrition				
mean% (range)	20% (4–75%)	32% (15–75%)	14% (4–51%)	20%
Internet Intervention				
Pre-fitting counseling	1	1	0	0
Aural rehabilitation	3	3	0	0
Acceptance & commitment therapy	2	1	1(treatment arm)	0
Cognitive Behavioral therapy	9	0	9	0
Vestibular Rehabilitation	1	0	0	1
Comparison (including separate treatment arms)				
<i>Inactive controls</i>				
Waiting list	4	3	1	0
Online discussion forum	5	1	4	0
Weekly check-in	1	0	1	0
Information only	1	0	1	0
<i>Active controls</i>				
Bibliotherapy	2	1	1	0
Group CBT	3	0	3	0
Individualized F2F	2	0	1	1
Efficacy trials	12	4	8	0
Effectiveness trials	3	1	1	1
Treatment arms				
2–arms	11	5	6	0
3–arms	2	0	2	0
4–arms	2	0	1	1

Timings				
<i>Latest follow-up period</i>				
2–4 months	3	1	2	0
6–9 months	5	2	2	1
1-year	5	0	5	0
Intervention duration				
4–5 weeks	4	4	0	0
6 weeks	3	0	2	1
8 weeks	5	1	4	0
up to 10 weeks	3	0	3	0
Sample size calculations				
provided	11	3	7	1

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1 **Table 3 Outcome measures used in the included studies**

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Measurement instrument	Number of items and subscales	Internal consistency (Cronbach's alpha)	Number in all included studies	Number in hearing loss Internet interventions	Number in tinnitus interventions	Number in vestibular Internet interventions
<i>Hearing disability</i>			5			
Hearing Handicap Inventory for the Elderly (Newman, Weinstein, Jacobson, & Hug, 1990)	25 items 2 subscales	0.93		4		
Hearing Handicap Questionnaire (Gatehouse & Noble, 2004)	12 items 2 subscales	0.94		1		
<i>Tinnitus distress/severity</i>			9			
Tinnitus Handicap Inventory (Newman, Jacobson, & Spitzer, 1996)	25 items 3 subscales	0.93			2	
Tinnitus Questionnaire (Goebel & Hiller, 1994)	52 items 5 subscales	0.94			1	
Tinnitus Reaction Questionnaire (Wilson, Henry, Bowen, & Haralambous, 1991)	26 items 4 subscales	0.96			3	
Tinnitus Functional Index (Meikle et al., 2012)	25 items 8 subscales	0.97			3	
<i>Vertigo/ dizziness</i>						
Vertigo Symptom Scale-Short Form (Wilhelmsen, Strand, Nordahl, Eide, & Ljunggren, 2008)	36 items 2 subscales	0.90	1			1

Anxiety			13	5	7	1
Hospital Anxiety and Depression Scale: anxiety subscale (Zigmond & Snaith, 1983)	7 items	Mean = 0.83	10	4	5	1
Generalized Anxiety Disorder (Lowe et al., 2008)	7 items	0.89	3	1	2	0
Depression			12	4	8	0
Hospital Anxiety and Depression Scale: depression subscale (Zigmond & Snaith, 1983)	7 items	Mean = 0.82	8	3	5	0
Patient Health Questionnaire (Spitzer, Kroenke, Williams, & Löwe, 2006)	9 items	0.83	3	1	3	0
Insomnia						
Insomnia Severity Index (Bastien, Vallières, & Morin, 2001)	7 items	0.74	6	0	6	0
Quality of Life			4	1	3	0
Quality of life Inventory (Frisch, Cornell, Villanueva, & Retzlaff, 1992)	16 items 2 subscales	Mean = 0.83	2	1	1	0
Satisfaction with life scales (Diener, Emmons, Larsen, & Griffin, 1985)	5 items	0.87	2	0	2	0
Long term outcomes			5	0	5	0

1 **Table 4. Summary of the included studies. Those with more than 1 active treatment arm have been subdivided to evaluate the effect of each treatment**
 2 **arm**

Reference	Country	Design	Intervention group	Control group	Between-group effect size: Cohens'd (95% CI)	Pre Mean (SD) Internet Intervention	Post Mean (SD) Internet Intervention	Pre Mean (SD) control	Post Mean (SD) control	Mean age Internet group (SD)	Gender Internet group	Post-intervention attrition & latest follow up period in months	Primary and relevant secondary outcome measures
Hearing													
Inactive controls													
Manchaiah et al. 2014 (H1)	UK	2-arm efficacy RCT	IPC n = 40	Waiting list n = 40	-0.37 (-1.09 to 0.36)	28.71 (6.42)	19.68 (7.49)	32.5 (7.7)	31.5 (9.4)	62.7 (10.64)	52% M 48% F	75% Post	HHQ HADS
Molander et al. 2018 (H2)	Sweden	2-arm efficacy RCT	IACT n = 31	Waiting list n = 30	0.93 (0.24 to 1.63)	26.2 (6.4)	22.4 (9.3)	29.33 (5.18)	24.25 (8.91)	59.36 (12.89)	33% M 67% F	39% Post	HHIE GAD-7 PHQ-9 QOLI
Thorén et al. 2011 (H3)	Sweden	2-arm efficacy RCT	IAR n = 29	Online discussion n = 30	0.40 (-0.11 to 0.92)	47.7 (16.3)	37.9 (16.7)	27.7 (5.5)	25.5 (5.8)	63.5 (13.3)	51% M 49% F	15% 6m	HHIE HADS
Thorén et al. 2014 (H4)	Sweden	2-arm efficacy RCT	IAR n = 38	Waiting list n = 38	0.49 (0.03 to 0.95)	42.0 (16.9)	35.8 (15.2)	48.5 (14.0)	45.5 (14.3)	69.3 (8.3)	58% M 42% F	16% 3m	HHIE HADS
Active controls													
Malmberg et al. 2017 (H5)	Sweden	2-arm effectiveness RCT	IAR n = 37	reading provided for one aspect (<i>bibliotherapy</i>) n = 37	-0.30 (-0.76 to 0.15)	35.80 (8.2)	34.89 (7.7)	36.1 (11.8)	31.3 (14.3)	61.8 (11.9)	65% M 35% F	16% 6m	HHIE HADS
Tinnitus													
Inactive controls													

Andersson et al. 2002 (T1)	Sweden	2-arm efficacy RCT	ICBT n = 53	Waiting-list n = 64	0.26 (-0.10 to 0.63)	42.6 (21.6)	29.5 (22.2)	38.2 (24.03)	35.4 (23.0)	48.5 (12.3)	54% M 46% F	51% ICBT 0% control 12m (n = 96 uncontrolled)	TRQ HADS
Beukes et al. 2018 (T2)	UK	2-arm efficacy RCT	ICBT n = 73	Weekly-check in n = 73	0.69 (0.35 to 1.02)	59.79 (17.95)	38.67 (24.26)	59.18 (19.96)	53.72 (19.38)	56.8 (12.2)	59% M 41% F	15% ICBT 1% control 4 m	TFI GAD-7, PHQ-9, ISI, SWLS
Hesser et al. 2012_ICBT (T3)	Sweden	3-arm efficacy RCT	ICBT n = 32	Online discussion forum n = 32	0.70 (0.20 to 1.20)	60.19 (14.59)	38.93 (19.72)	60.94 (14.79)	49.94 (16.09)	48.8 (13.4)	56% M 44% F	6% ICBT 0% control 12 (n = 30 uncontrolled)	THI HADS ISI QOLI
Hesser et al. 2012_IACT (T4)	Sweden	3-arm efficacy RCT	IACT n = 35	Online discussion forum n = 32	0.68 (0.18 to 1.17)	52.74 (12.90)	31.94 (14.54)	60.94 (14.79)	49.94 (16.09)	50.1 (16.4)	57% M 43% F	6% IACT 0% control 12 (n = 31 uncontrolled)	THI HADS ISI QOLI
Jasper et al. 2014 (T5)	Germany	3-arm efficacy RCT	ICBT n = 41	Online discussion forum n = 44	0.54 (0.11 to 0.98)	40.34 (17.64),	26.67 (20.75)	40.23 (20.54)	37.46 (18.94)	51.3 (9.8)	61% M 39% F	7% ICBT 2% control 6m	THI HADS ISI
Nyenhuis et al 2013_IO (T6)	Germany	4-arm efficacy RCT	ICBT n = 79	Information only n = 77	0.63 (0.31 to 0.95)	35.8 (13.4)	17.6 (12.7)	34.5 (13.0)	27.4 (18.0)	47.8 (12.5)	53% M 47% F	24% ICBT 36% control	TQ PHQ-9

												9m		
Weise et al. 2016 (T7)	Germany	Efficacy RCT	ICBT n = 62	Online discussion forum n = 62	0.83 (0.46 to 1.21)	53.39 (14.90)	32.56 (16.50)		45.77 (15.06)	47.8 (12.3)		40% M 60% F	6% ICBT 2% control 12m (n = 55 uncontrolled)	THI HADS ISI
Active control														
Beukes et al. 2018a (T8)	UK	2-arm effectiveness RCT	ICBT n = 46	Individualized F2F n = 46	0.30 (-0.11 to 0.72)	55.01 (21.58)	27.88 (20.84)		34.88 (24.91)	50.7 (12.2)		63% M 37% F	4% ICBT 4% control 2 m	TFI GAD-7 PHQ-9, ISI, SWLS
Jasper et al. 2014 (T9)	Germany	3-arm efficacy RCT	ICBT n = 41	Group-based CBT n = 43	0.48 (0.05 to 0.90)	40.34 (17.64)	26.67 (20.75)		27.7 (21.93)	51.3 (9.8)		61% M, 39% F	7% ICT 7% GCBT 6m	THI HADS ISI
Kaldo et al 2008 (T10)	Sweden	Efficacy RCT, active control	ICBT n = 26	Group-based CBT n = 25	0.04 (-0.51 to 0.59)	26.4 (15.6)	18.0 (16.2)		18.6 (17.0)	47.4 (12.9)		58% M 42% F	4% ICBT 4% GCBT 12m (uncontrolled)	TRQ HADS ISI
Nyenhuis et al 2013_GCT B (T11)	Germany	4-arm efficacy RCT	ICBT n = 79	GCBT n = 71	0.23 (-0.09 to 0.56)	35.8 (13.4)	17.6 (12.7)		20.8 (14.7)	47.8 (12.5)		53% M 47% F	24% ICBT 34% GCBT 9m	TQ PHQ-9
Nyenhuis et al 2013 (T12)	Germany	4-arm efficacy RCT	ICBT n = 79	Bibliotherapy n = 77	0.51 (0.19 to 0.83)	35.8 (13.4)	17.6 (12.7)		26.3 (20.4)	47.8 (12.5)		53% M 47% F	24% ICBT 9m 34% bibliotherapy	TQ PHQ-9

Long term outcomes not included in previous studies														
Beukes et al. 2018b_long term (T13)	UK	Single group	ICBT <i>n</i> = 104	None	0.69 (0.28-0.61) within group	59.49 (18.40)	36.79 (24.84)		NA	58.3 (12.5)		56% M 44% F	0% ICBT 12 (uncontrolled)	TFI GAD-7, PHQ-9, ISI, SWLS
VESTIBULAR						Internet group median (IQR) pre	Internet group median (IQR) pre	Usual care Median (IQR) pre	Usual care Median (IQR) post					
Active control														
Geraghty et al. 2017 (V1)	UK	Effectiveness RCT	IVR <i>n</i> = 160	Usual care <i>n</i> = 136	VSS-SF	14 (8-22)	6 (3-12)	13 (7-22)	9 (5-15)	67.3 (9.0)	33% M 67% F	16% 6m	VSS-SF HADS	

1 Note: Data from T3, T4, H4 corrected in meta-analysis due to significant group differences between groups. Difference scores together with the pooled standard
2 deviations were used for effect size calculations.
3 Acronyms:
4 F2F: Face to Face; HHIE: Hearing Handicap Inventory for the elderly; HHQ: Hearing Handicap Questionnaire; IACT: Internet-based Acceptance and
5 commitment therapy; IAT: Internet-based auditory training; IAR: Internet-based aural rehabilitation; ICBT: Internet-based cognitive behavioral therapy; IPC:
6 Internet-based pre-fitting counseling; IQR: Interquartile range; IVR: Internet-based vestibular rehabilitation; F: Female; GAD-7: Generalized Anxiety Disorder;
7 HA: Hearing aid; HADS: Hospital Anxiety and Depression Scale; HHQ: Hearing handicap questionnaire; M: male; PDDS: Psychosomatic discomfort and
8 depressive symptoms; PHQ-9: Patient health questionnaire; QOLI: Quality of life Inventory (Frisch, Cornell, Villanueva and Retzlaff, 1992); RCT: Randomized
9 controlled trial; SWLS: Satisfaction with life scales; TFI: Tinnitus Functional Index; UK: United Kingdom; USA: United States of America; VSS-SF: Vertigo
10 Symptom Scale-Short Form
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1 **Table 5 Summary of findings for the primary and long-term outcomes**

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Summary		Effect		Heterogeneity		Quality	
Internet Intervention	Comparator	Participants (references*)	Pooled between-group Cohen's <i>d</i> , (95% CI)	Test for overall effect: <i>z</i> (<i>p</i>)	Q-value, (df), significance	Tau ² and I ²	Quality of evidence (GRADE)
Hearing loss	All controls	<i>n</i> = 350 5 studies (H1–5)	0.35 (-0.02 to 0.72) <i>p</i> = 0.07	2.28 <i>p</i> = 0.02*	16.19 (4) <i>p</i> = 0.003*	0.11 60%	⊕⊕ Low
	Inactive controls	<i>n</i> = 276 4 studies (H1–4)	0.41 (-0.04 to 0.86) <i>p</i> = 0.07	3.40 <i>p</i> = 0.001*	8.15 (3) <i>p</i> = 0.04*	0.13 63%	⊕⊕ Low
	Inactive controls, moderated by attrition	<i>n</i> = 236 3 studies (H2–5)	0.59 (0.29-0.90) <i>p</i> = 0.001*	4.05 <i>p</i> = 0.001*	2.32 (2) <i>p</i> = 0.31	0.01 14%	
	Active controls	<i>n</i> = 74 1 study (H5)	0.10 (-0.36 to 0.55) <i>p</i> = 0.68				⊕ Very low
Tinnitus	All controls	<i>n</i> = 1,277 12 studies (T1–12)	0.50 (0.37 to 0.63) <i>p</i> = 0.01*	8.80 <i>p</i> = 0.01*	13.89 (11) <i>p</i> = 0.24	0.01 21%	⊕⊕⊕ Moderate
	Inactive controls	<i>n</i> = 744 7 studies (T1–7)	0.61 (0.47 to 0.72) <i>p</i> = 0.001*	8.19 <i>p</i> = 0.01*	5.37 (6) <i>p</i> = 0.50	0.00 0%	⊕⊕⊕ Moderate
	Active controls	<i>n</i> = 377 5 studies (T8–12)	0.35 (0.18 to 0.52) <i>p</i> = 0.001*	3.97 <i>p</i> = 0.001*	3.15 (4) <i>p</i> = 0.53	0.00 0%	⊕⊕⊕ Moderate
1 year outcomes: tinnitus distress							

Tinnitus long-term outcome	All controls	<i>n</i> = 517 6 studies (T1, T3-4, T7, T10, T13)	Within and between group comparison 0.43 (0.27 to 0.59); <i>p</i> = 0.001*	15.16 <i>p</i> < 0.001	32.95 (5) <i>p</i> = 0.001*	0.03 85%	⊕⊕ Low
	Inactive controls	<i>n</i> = 466 5 studies (T1, T3-4, T7, T13)	Within group comparison: 0.45 (0.28 to 0.61) <i>p</i> = 0.001*	5.35 <i>p</i> = 0.001*	31.97 (4) <i>p</i> = 0.001*	0.03 87%	⊕⊕ Low
	Active control	<i>n</i> = 51 1 study (T10)	0.01 (-0.40 to 0.42) <i>p</i> = 0.96*				
*for the full references please refer to Table 4							

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Table 6: Summary of findings for the secondary outcomes

Outcome	Summary			Effect		Heterogeneity		Quality
	Internet Intervention	Comparator	Participants (references*)	Pooled between-group Cohen's <i>d</i> , (95% CI)	Test for overall effect: <i>z</i> (<i>p</i>)	Q-value, (df), significance	Tau ² and I ²	Quality of evidence (GRADE)
Anxiety	Hearing loss	All controls	n = 350 5 studies (H1-5)	0.02 (-0.21 to 0.25) <i>p</i> = 0.86	0.17 <i>p</i> = 0.86	1.18 (4) <i>p</i> = 0.88	0.00 0%	⊕⊕ Low
		Inactive controls	n = 276 4 studies (H1-4)	0.02 (-0.24 to 0.28) <i>p</i> = 0.90	0.13 <i>p</i> = 0.90	1.18 (3) <i>p</i> = 0.76	0.00 0%	⊕⊕ Low
		Active controls	n = 74 1 study (H5)	-0.03 (-0.49 to 0.42), <i>p</i> = 0.89				⊕ Very low
	Tinnitus	All controls	n = 1121 9 studies (T1-5, T7-10)	0.35 (0.21 to 0.49), <i>p</i> = 0.001*	4.65 <i>p</i> = 0.001*	9.17 (8) <i>p</i> = 0.33	0.01 13%	⊕⊕⊕ Moderate
		Inactive controls	n = 744 6 studies (T1-5, T7)	0.41 (0.25 to 0.57), <i>p</i> < 0.001*	4.94 <i>p</i> = 0.001*	4.95 (5) <i>p</i> = 0.42	0.00 0%	⊕⊕⊕ Moderate
		Active controls	n = 377 3 studies (T8-10)	0.20 (-0.09 to 0.48) <i>p</i> = 0.17	1.36 <i>p</i> = 0.17	2.35 (2) <i>p</i> = 0.31	0.01 15%	⊕⊕ Low
Depression	Hearing loss	All controls	n = 270 4 studies (H2-5)	0.29 (0.3 to 0.55) <i>p</i> = 0.03*	2.20 <i>p</i> = 0.03	3.48 (3) <i>p</i> = 0.32	0.01 14%	⊕⊕ Low

		Inactive controls	n = 196 3 studies (H2–4)	0.41 (0.13 to 0.70) $p < 0.001^*$	2.86 $p = 0.004^*$	0.82 (2) $p = 0.66$	0.00 0%	⊕⊕ Low
		Active controls	n = 74 1 study (H5)	-0.03 (-0.49 to 0.42) $p = 0.88$				⊕ Very low
	Tinnitus	All controls	n = 1292 12 studies (T1–12)	0.21 (0.10 to 0.32) $p = 0.001^*$	3.68 $p < 0.001^*$	8.0 (11), $p = 0.66$	0.00 0%	⊕⊕⊕ Moderate
		Inactive controls	n = 759 7 studies (T1–7)	0.28 (0.13 to 0.42) $p < 0.001^*$	3.76 $p < 0.001$	1.70 (6), $p = 0.95$	0.00 0%	⊕⊕⊕ Moderate
		Active controls	n = 533 5 studies (T8–12)	0.11 (-0.08 to 0.29) $p = 0.26$	1.25 $p = 0.21$	4.71 (4), $p = 0.32$	0.00 15%	⊕⊕ Low
Insomnia	Tinnitus	All controls	n = 713 8 studies (T2–T5, T7–T10)	0.42 (0.27 to 0.57) $p < 0.001^*$	5.49 $p < 0.0001$	5.09 (7), $p = 0.65$	0.00 0%	⊕⊕⊕ Moderate
		Inactive controls	n = 486 5 studies (T2–5, T7)	0.47 (95% CI, 0.29 to 0.65) $p < 0.001$	5.09 $p < 0.001$	2.94 (4), $p = 0.57$	0.00 0%	⊕⊕⊕ Moderate
		Active controls	n = 227 3 studies (T8–T10)	0.31 (0.05 to 0.57) $p = 0.02^*$	2.30 $p = 0.02^*$	1.12 (2), $p = 0.57$	0.00 0%	⊕⊕ Low
Quality of life	Hearing Loss	Hearing: active control	n = 430 1 study (H2)	0.88 (0.35 to 1.40) $p < 0.001^*$				⊕ Very low
	Tinnitus	All controls	n = 369 4 studies (T2-4, T8)	0.18 (-0.02 to 0.39) $p = 0.08$	1.77 $p = 0.08$	1.62(3) $p = 0.66$	0.00 0%	⊕⊕ Low

		Inactive controls	n = 277 3 studies (T2-4)	0.24 (0.00 to 0.48) <i>p</i> = 0.05	1.98 <i>p</i> = 0.05*	0.71 (2), <i>p</i> = 0.70	0.00 0%	⊕⊕ Low
		Active control	n = 92 1 study (T8)	0.01 (-0.40 to 0.42) <i>p</i> = 0.96				⊕ Very low
*For the full references please refer to Table 4								

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