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Improving Health-Related Quality of Life in Single-Sided Deafness: A Systematic Review and Meta-Analysis

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Key Words

Asymmetric hearing loss · Cochlear implantation · CROS · Disease-specific instruments · Generic instruments · Health-related quality of life · Hearing-assistive devices · Single-sided deafness

Abstract

Unilateral severe-to-profound hearing loss, or single-sided deafness (SSD), impairs listening abilities supported by the use of two ears, including speech perception in background noise and sound localisation. Hearing-assistive devices can aid listening by re-routing sounds from the impaired to the non-impaired ear or by restoring input to the impaired ear. A systematic review of the literature examined the impact of hearing-assistive devices on the health-related quality of life (HRQoL) of adults with SSD as measured using generic and disease-specific instruments. A majority of studies used observational designs, and the quality of the evidence was low to moderate. Only two studies used generic instruments. A mixed-effect meta-analysis of disease-specific measures suggested that hearing-assistive devices have a small-to-medium impact on HRQoL. The Speech, Spatial and Qualities of Hearing Scale and the Health Utilities Index Mark 3 (HUI3) were identified as instruments that are sensitive to device-related changes in disease-specific and generic HRQoL, respectively.

Introduction

A severe-to-profound hearing loss in one ear only, or single-sided deafness (SSD), can have a measurable and detrimental impact on many aspects of hearing [Douglas et al., 2007]. With only one functional ear, the binaural cues of interaural time and intensity that underpin sound localisation are absent or distorted. Hearing with one ear only also means that sounds that are located towards the impaired ear are attenuated when arriving at the non-impaired ear. This attenuation, or head shadow, caused by the diffraction of sound waves as they travel around the head can compromise the ability to understand speech in noisy environments [Taylor, 2010].

A range of hearing-assistive devices have been developed to address some of the functional impairments caused by SSD [Bishop and Eloy, 2010]. Devices which re-route sounds arriving on the side of the impaired ear to the non-impaired ear can help overcome the head shadow. CROS (contralateral routing of signals) can improve speech perception in noise when the signal-to-noise ratio is more favourable at the impaired ear than the non-impaired ear. This effect has been observed regardless of whether the re-routing is achieved through air or bone conduction [Baguley et al., 2006]. Useful aspects of binaural hearing may also be restored through cochlear implants (CIs), which have the capacity to support better-ear listening and to provide access to interaural intensity cues. Although binaural hearing following cochlear implantation in SSD requires the listener to integrate electric and acoustic information, studies have demonstrated that implantation can improve localisation and speech understanding in noise [Kamal et al., 2012].

Despite having access to an unimpaired or minimally impaired ear, individuals with SSD report substantial difficulties with listening in many everyday situations and can report a level of psychological distress that may appear disproportionate to their level of residual acoustic hearing [McLeod et al., 2008]. Therefore, when evaluating the benefits of hearing-assistive devices for SSD, it is relevant to use outcome measures that can assess the impact on a patient's overall health and well-being, or health-related quality of life (HRQoL). Instruments for measuring HRQoL can be classified as generic or disease specific. These approaches differ in whether they measure the impact on dimensions of health chosen to be relevant to a wide range of health conditions or to be relevant to a particular disease. A systematic review of the literature was conducted to establish the extent to which current hearing-assistive devices can have an impact on HRQoL in adults with SSD, whether the size of that impact differs between devices, and whether impact has been demonstrated using both generic and disease-specific instruments.

Methods

This review was conducted according to published recommendations for identifying, grading, synthesizing and reporting evidence from studies of health interventions [Centre for Reviews and Dissemination, 2009; Higgins and Green, 2009; Moher et al., 2009]. The criteria for inclusion, quality assessment, and meta-analysis were defined prospectively. Articles were identified by executing an electronic search of MEDLINE, EMBASE, PubMed, DARE, and Cochrane databases on 26th February 2014. No restrictions were imposed on language and the search included articles published from 1946 onwards. The search strategy requested articles whose title and/or abstract included: (a) at least one term relating to SSD ('unilateral', 'single-sided', 'hearing loss', 'deafness') or that were

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assigned the Medical Subject Heading term 'hearing loss, unilateral' and (b) at least one term relating to devices ('implant*', 'device*', 'prosthes*', 'instrument*', 'hearing aid*') or were assigned related Medical Subject Heading terms ('bone conduction', 'hearing aids', 'cochlear implants', 'auditory brain stem implants', 'dental implants', 'ossicular prosthesis').

The criteria for inclusion in the review were specified in terms of PICOS (Participants, Interventions, Comparators, Outcomes and Study Design). The participants were adults with unilateral severe-to-profound sensorineural hearing loss defined as (1) a pure-tone average >70 dB HL in one ear with an air-bone gap ≤10 dB and (2) a pure-tone average ≤30 dB HL in the other ear. The interventions were any hearing-assistive device, including, but not limited to, air (ACDs) or bone conduction devices (BCDs), CROS and CIs. The comparators were placebo devices or no treatment (unaided). Eligible outcomes included validated generic and disease-specific instruments for measuring changes in HRQoL. No restrictions were placed on the study design. Articles were permitted to include multiple populations, but outcomes for the eligible population had to be reported separately.

Titles and abstracts were retrieved and independently assessed against the PICOS criteria by two of the authors. At this stage, articles were excluded only if both reviewers agreed that the criteria had not been met. The full text of the remaining articles was retrieved and a secondary assessment was performed independently by the same two authors. Disagreements about whether an article satisfied the criteria were resolved by consensus. Articles included in the review were subjected to a quality assessment. Two authors independently assessed whether each article indicated that (a) the allocation to group/intervention was randomised; (b) allocation was concealed; (c) ethical approval had been obtained; (d) data collection was prospective; (e) inclusion and exclusion criteria were defined; (f) a power calculation was conducted; (g) a control group was included; (h) missing data were declared, and (i) sources of funding were reported. Each study was assigned an evidence level [Centre for Evidence-Based Medicine, 2009] and disagreements between reviewers that arose in conducting the quality assessment were resolved by consensus.

Data on eligible outcomes were extracted independently by two authors. Discrepancies in the data extracted that had been transcribed from the text of an article were resolved by a third author. Where data had to be extracted from figures or illustrations, the average of the values estimated by the two authors was used. Efforts were made to contact authors where published data provided insufficient information to calculate effect sizes. All effect sizes were calculated as standardised mean differences (SMDs) in which the mean difference between aided and unaided conditions was standardised by dividing it by the standard deviation of the differences (within-subject effects from repeated-measure designs) [Gibbons et al., 1993] or by the pooled standard deviation (between-group comparisons) [Hedges, 1981]. For between-group comparisons, effect sizes were categorised as small, medium or large if their value exceeded 0.2, 0.5 and 0.8, respectively [Cohen, 1988]. Barcikowski and Robey [1985] suggested that equivalent thresholds for within-subject effects could be obtained by dividing these values by $\sqrt{1-\rho}$ where ρ is the correlation between scores before and after intervention. The resulting thresholds for within-subject effects were 0.3, 0.8 and 1.2 based on an average pre-post correlation of 0.56.

For studies that adopted a repeated-measure (pre-post) design, an effect size was calculated if the means and standard deviations for the conditions before and after intervention were reported along with the correlation between the two measures. Effect sizes could also be derived from the mean and standard deviation of the pre-post differences, if reported. Where standard deviations or correlations were not reported, they were imputed from other observational studies that used the same outcome measure and intervention. An average effect size was calculated where an article reported outcomes at multiple time points after intervention. For studies that compared two groups, effect sizes were calculated from the means and standard deviations within each group. If required, effect sizes were also calculated from the values of test statistics or their probability values if the methodology was reported in sufficient detail. Comparisons between effect sizes and a mixed-effect meta-analysis were conducted using the metafor package for the R statistical software [Viechtbauer, 2010].

Results

Of the 334 articles retrieved from the electronic databases, 34 articles were unanimously excluded based on titles and abstracts alone, and full texts were retrieved for the remaining 300 articles. Twenty-four articles were deemed to have met the inclusion criteria and were included in the review (table 1). A further 20 articles had satisfied the PICOS criteria but were excluded because data from adults with SSD were not reported separately from other populations. Two articles reported outcomes from the same group of patients but after different durations of follow-up [Arndt et al., 2011a, b].

The majority of studies were non-experimental pre-post observational studies in which participants acted as their own controls (level of evidence 4). Two studies included control groups where the allocation to groups was not at random (level of evidence 3b) [Gluth et al., 2010; House et al., 2010] and one study used randomisation to determine the order in which participants used two hearing-assistive devices (level of evidence 1b) [Moore and Popelka, 2013]. However, participants acted as their own controls when comparing HRQoL in the aided and unaided conditions in all but one study [House et al., 2010]. The results of the quality assessment are listed in table 1. While the majority of studies were prospective, several studies did not clearly specify inclusion/exclusion criteria or declare whether there were any missing data and, if so, how it was handled. Many studies did not state whether ethical approval was required or obtained, and did not declare sources of funding. Only one study reported conducting a power calculation.

Two studies reported changes in HRQoL measured using generic instruments. Newman et al. [2008] reported outcomes before and after BCD use in terms of scores on the 36-item Short-Form Health Survey (SF-36) [Ware and Sherbourne, 1992]. The SF-36 includes questions about impairments to eight health dimensions, including physical function, social function and mental health. However, estimates of variability were not reported, so effect sizes could not be calculated. Arndt et al. [2011a] measured the HRQoL of 11 adults with SSD using the Health Utilities Index Mark 3 (HUI3) [Feeny et al., 1995]. The HUI3 was administered before any intervention, after 3-week trials of an ACD and a BCD worn on a headband, and 6 months after CI surgery. The HUI3 classifies the degree of impairment on eight health dimensions, including hearing and speech. The HUI3 can be used to derive a utility value

Table 1. Characteristics of studies included in the review

First author, year	n (SSD)	Intervention(s)	HRQoL outcomes	Controls	Grade	Quality assessment								
						1	2	3	4	5	6	7	8	9
Arndt, 2011a, b	11	CI, BCD, ACD	SSQ, HUI3	Own	4	–	–	+	+	+	–	–	?	–
Barbara, 2010	7	BCD	GBI	Own	4	–	–	–	+	–	–	–	+	–
Bosman, 2003	9	BCD, ACD	APHAB	Own	4	–	–	–	+	–	–	–	?	–
Desmet, 2012	10	BCD	APHAB, SHQ	Own	4	–	–	+	+	–	–	–	?	–
Dumper, 2009	15	BCD	APHAB, SSQ	Own	4	–	–	–	+	+	–	–	?	–
Firszt, 2012	3	CI	SSQ	Own	4	–	–	+	+	+	–	–	+	+
Gluth, 2010	56	BCD	APHAB, GHABP	SSD	3b	–	–	+	+	+	–	–	+	–
Hassepass, 2013	2	CI	SSQ	Own	4	–	–	+	+	–	–	–	+	–
Hol, 2010	10	BCD, ACD	APHAB, SSQ	Own	4	–	–	–	+	–	–	–	+	–
House, 2010	129	BCD	SSQ, APHAB	SSD	3b	–	–	–	?	–	–	+	+	+
Lin, 2006	23	BCD, ACD	APHAB	Own	4	–	–	+	+	–	–	–	+	+
Moore, 2013	9	BCD	APHAB	SSD	1b[2]	+	–	–	+	+	–	+	?	+
Murray, 2011	22	BCD	APHAB	Own	4	–	–	–	+	+	–	–	?	+
Newman, 2008	10	BCD	APHAB, HHIA[1], SF-36[1]	Own	4	–	–	+	+	–	–	–	?	+
Niparko, 2003	10	BCD, ACD	APHAB, GHABP	Own	4	–	–	+	+	+	–	–	?	–
Oeding, 2010	16	BCD	APHAB	Own	4	–	–	+	+	+	+	–	?	+
Pai, 2012	25	BCD	SSQ	Own	4	–	–	–	+	+	–	–	?	–
Saliba, 2011	21	BCD	APHAB	Own	4	–	–	+	+	+	–	–	?	–
Tavora-Vieira, 2013a	5	CI	SSQ	Own	4	–	–	+	+	+	–	–	?	–
Tavora-Vieira, 2013b	9	CI	SSQ	Own	4	–	–	+	+	+	–	–	?	+
Vermeire, 2009	20	CI	SSQ	Own	4	–	–	+	+	–	–	–	?	–
Wazen, 2003	18	BCD, ACD	APHAB	Own	4	–	–	–	+	–	–	–	?	+
Yuen, 2009	21	BCD	APHAB, GHABP	Own	4	–	–	+	+	–	–	–	?	+

Quality assessment: (1) randomisation; (2) concealment; (3) ethical approval; (4) prospective; (5) eligibility criteria; (6) power calculation; (7) control group; (8) missing data, and (9) funding source. + = Clearly present; – = clearly absent; ? = unclear. GBI = Glasgow Benefit Inventory; HHIA = Hearing Handicap Inventory for Adults.

[1] Effect sizes could not be calculated from the data included in the study report. [2] Evidence for BCD relative to the unaided condition (pre-post) graded as level 4.

which expresses the health state of the respondent on a scale from 0 to 1 based on the preferences of a random sample of the Canadian public [Furlong et al., 1998]. Effect sizes for both CROS devices had 95% confidence intervals (CIs) that embraced zero, with a smaller effect observed after ACD use (mean 0.26, 95% CI –0.37 to 0.89) than after BCD use (mean 0.46, 95% CI –0.16 to 1.1). CI was associated with the largest-observed effect size of 0.69 (95% CI 0.03–1.35). Although this result would be considered a medium effect size according to the thresholds proposed by Cohen [1988], it was classified as a small effect once the correlation between values before and after intervention was taken into account [Barcikowski and Robey, 1985].

All studies included disease-specific measures of HRQoL. The most frequently adopted measure was the Abbreviated Profile of Hearing Aid Benefit (APHAB, 15 studies). The APHAB includes four subscales: background noise (BN), reverberation (RV), ease of communication (EC) and aversion to sounds (AV) [Cox and Alexander, 1995]. Ten studies included the Speech, Spatial and Qualities of Hearing Scale (SSQ) [Gatehouse and Noble, 2004] and three studies included the Glasgow Hearing Aid Benefit Profile (GHABP) [Gatehouse, 1999]. Individual studies also included the Glasgow Benefit Inventory [Robinson et al., 1996], the Spatial Hearing Questionnaire (SHQ) [Tyler et al., 2009] and the Hearing Handicap Inventory for Adults (HHIA) [Newman et al., 1990]. The studies evaluated the impact of ACD, BCD and CI on HRQoL. Bone conduction interventions included devices mounted on head bands, on ossio-integrated abutments and on dental fixtures. However, as the objective of this review was to examine the impact of general device classes on HRQoL, effect sizes were grouped according to whether the intervention was an ACD, BCD or CI.

Effect sizes associated with the use of an ACD were derived from APHAB and SSQ scores (fig. 1). Mean effect sizes ranged from –0.69 to 1.00 with the 95% CIs embracing zero for a majority of the effects. Negative effects were found for the AV subscale of the APHAB and the sections of the SSQ that dealt with speech and the quality of sounds. The largest positive effects were found for the BN and RV subscales of the APHAB and the spatial section of the SSQ. A similar pattern of effects was found for BCD use (fig. 2), for which studies reported negative effects on HRQoL related to sound aversion and quality, and positive effects related to RV, BN, spatial listening and speech perception. Over half of the observed effects of BCD use had 95% CIs that did not embrace zero. Effect sizes for CIs were derived exclusively from SSQ data (fig. 3). All but two CI effects had 95% CIs that did not embrace zero, and effect sizes ranged from 0.22 to 4.54.

Estimated mean effect sizes for each category of hearing-assistive device were derived from a mixed-effect meta-analysis of disease-specific HRQoL data. The mean effect size obtained using disease-specific instruments was influenced by device type [$QM(2) = 12.93$, $p < 0.01$]. All three devices had a statistically significant impact on HRQoL, with the smallest effect found for ACD (mean 0.26, 95% CI 0.05–0.46), a larger effect for BCD (mean 0.55,

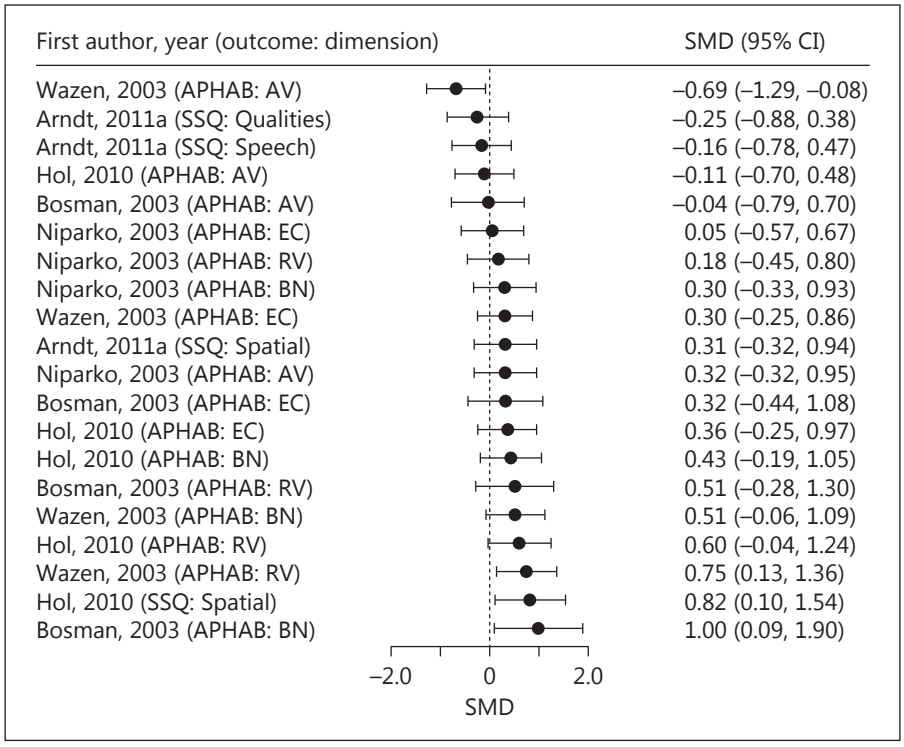


Fig. 1. Effect sizes associated with the use of an ACD compared to the unaided condition. Effect sizes were obtained using disease-specific measures and are expressed as SMDs. Error bars plot 95% CIs.

95% CI 0.45–0.66) and the largest effect for CI (mean 0.92, 95% CI 0.61–1.24). An analysis comparing disease-specific and generic effect sizes was not conducted as the generic estimate would reflect data from a single study only [Arndt et al., 2011a].

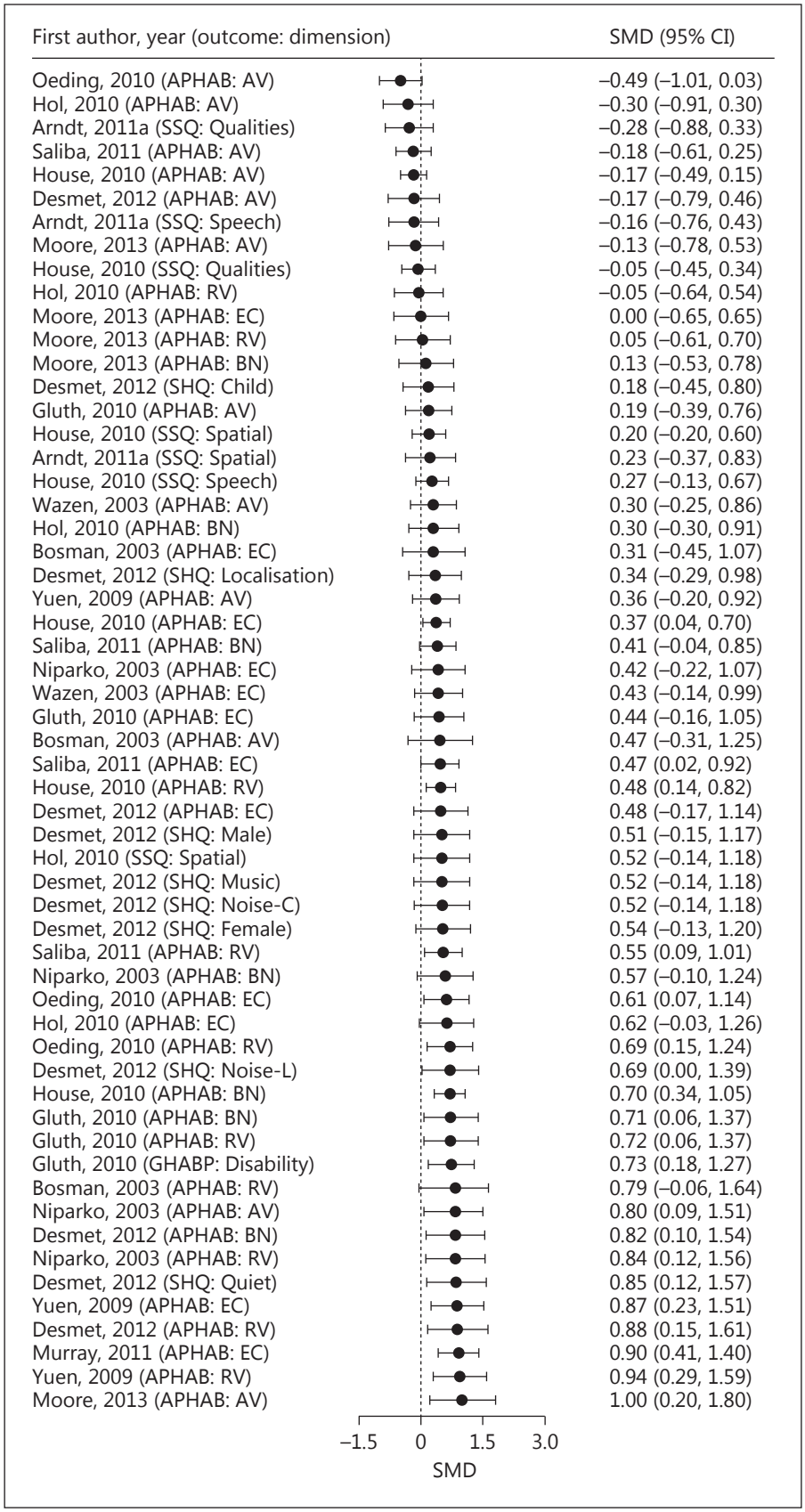
Discussion

This study aimed to summarise the current evidence for the effects of hearing-assistive devices on the HRQoL of adults with SSD. A search of five electronic databases identified 23 studies reported across 24 articles, the majority of which were non-experimental observational studies in which participants acted as their own control. The results of a mixed-effect meta-analysis suggested that ACD, BCD and CI all have the capacity to improve HRQoL as measured using disease-specific instruments. The improvements resulted from reductions in difficulty with understanding speech in BN and RV, and in determining the location of sounds.

Only two studies measured impacts on HRQoL using generic instruments [Newman et al., 2008; Arndt et al., 2011a]. Generic approaches to measuring HRQoL seek to capture changes to health described in terms of a set of dimensions that have been selected to (a) reflect aspects of health that could limit a person's independence and to engage in social and vocational activities and (b) are relevant to a broad range of health conditions. The primary advantage of generic instruments is that they permit comparisons of health benefits across different health services and can therefore inform resource allocation decisions within health care systems [Drummond et al., 2005].

The data reported by Arndt et al. [2011a] demonstrate that CROS devices and cochlear implantation can have small effects on generic HRQoL when measured using the HUI3. This finding is compatible with previous studies which have observed that the HUI3 is sensitive to hearing-related interventions such as hearing aids [Barton et al., 2004] and CIs [UK Cochlear Implant Study Group, 2004] in patients with a bilateral hearing loss. The limited available data therefore suggest that the HUI3 is a generic measure that is sensitive to the effects of hearing-assistive devices on HRQoL in SSD. While no effect size could be computed for the SF-36 data reported by Newman et al. [2008], the user manual for the SF-36 suggests that group mean scores below 47 are below average [Maruish, 2011]. The mean data extracted from Newman et al. [2008] indicated that social functioning and emotional role function were below average in adults with SSD and improved to average levels after BCD use. The results of these two studies provide preliminary evidence that the impact of hearing-assistive devices on HRQoL can be detected using generic instruments.

A disease-specific approach to measuring HRQoL is attractive because the instruments are designed to be sensitive to the impact of the disease and to the benefits of related interventions [Bess, 2000]. However, the output from a disease-specific instrument is not directly relatable to that of a generic instrument unless both have been developed to provide output values reflecting the preferences ('utilities') of a population [Abrams et al., 2005]. Disease-specific measures of HRQoL, such as the APHAB, that profile a patient on one or more dimensions face the same limitation as disease-specific measures of function (e.g. sound localisation and speech perception) as they are of limited value to commissioners of health care services whose perspective encompasses the health care system as a whole rather than one aspect of it. Instead, profile instruments are informative in measuring clinically relevant changes in outcomes on scales easily interpretable by those treating patients with hearing loss [Chisolm et al., 2007].



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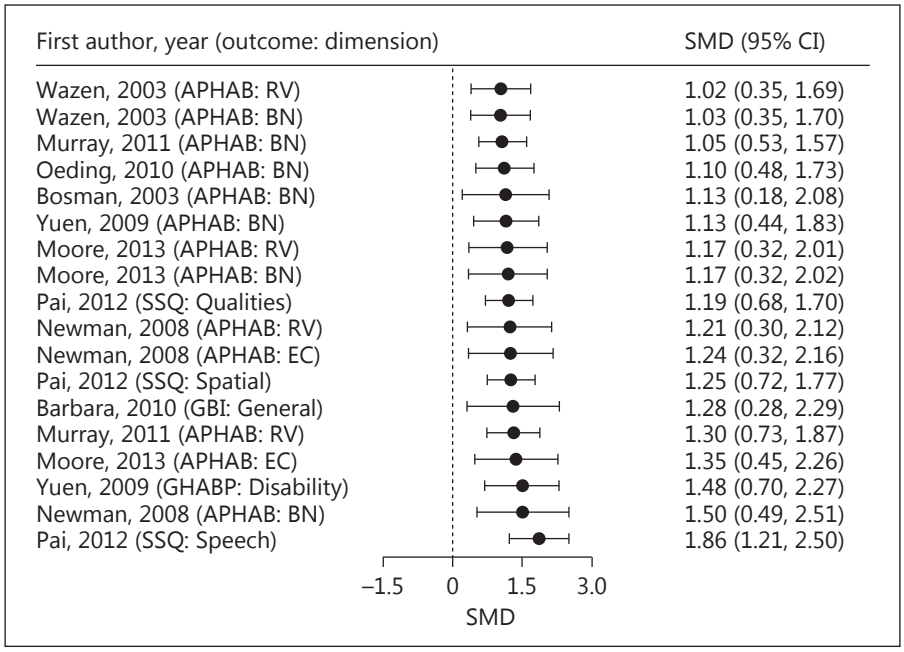

Fig. 2. Effect sizes for BCDs compared to the unaided condition obtained using disease-specific instruments. GBI = Glasgow Benefit Inventory.

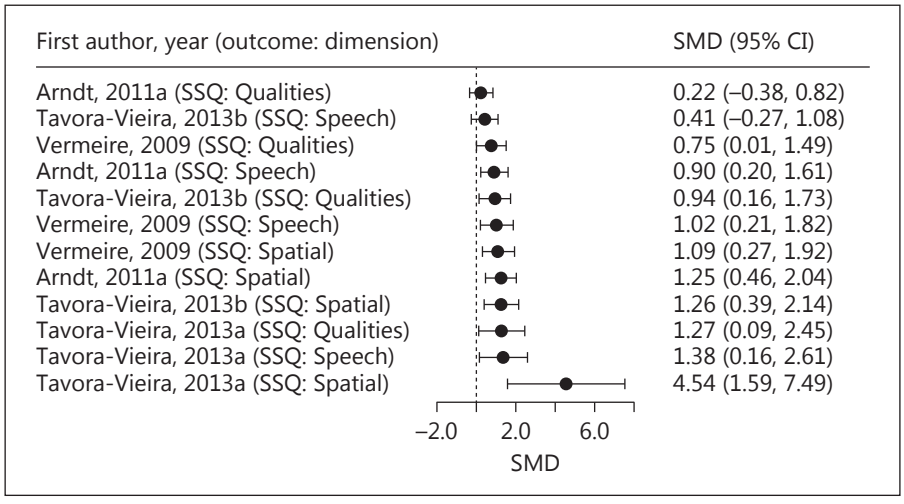

Fig. 3. Effect sizes for CIs compared to the unaided condition obtained using disease-specific instruments.

Disease-specific effect sizes were derived from within-subject comparisons of the aided and unaided conditions in all but one study [House et al., 2010]. The majority of the reported effects may therefore have been influenced by some form of selection bias, i.e. patients could have inadvertently been selected for inclusion or assigned a device based on factors other than their level of hearing loss that may not have been specified in the published report. In a small subset of studies, it was unclear whether the unaided condition was evaluated before or after provision of a hearing-assistive device. Other studies stated that the unaided condition was assessed after patients had used the hearing-assistive devices for some time [Dumper et al., 2009]. It is possible that patients assessed under these circumstances may value their unaided HRQoL differently than those who have no experience with the use of any hearing-assistive device. Some caution should, therefore, be taken about generalising these results to the wider population of adult patients with SSD.

The current review identified a wide range of disease-specific instruments that have been used to measure HRQoL when evaluating the use of hearing-assistive devices for SSD in adults. Either the APHAB or the SSQ was used in all but one of the 23 studies. Both instruments include questions relating to the perception of speech in BN, the difficulties with listening in a range of everyday environments and the effort required to listen. In addition, the SSQ asks about difficulties with locating sounds and judging the distance of sounds. These are abilities that are reported as being particularly impaired by individuals with SSD [McLeod et al., 2008] and by those with an asymmetric hearing loss more generally [No-

ble and Gatehouse, 2004]. The SSQ was also the only instrument to have been used in evaluations of devices in all three categories, i.e. ACD, BCD and CI.

An additional mixed-effect meta-analysis was conducted using SSQ data alone to determine whether the SSQ is sensitive to the impact of all three device categories on HRQoL. Estimated mean effect sizes obtained using the SSQ alone were similar to those derived across all disease-specific instruments (ACD 0.17, BCD 0.49 and CI 0.96) and SSQ data were also significantly influenced by device type [$QM(2) = 6.21$, $p < 0.05$]. The analysis revealed significant effects of BCD use (95% CI 0.15–0.82) and of cochlear implantation (95% CI 0.58–1.33). Although the SSQ did not detect a statistically significant impact of ACD on HRQoL (95% CI –0.40 to 0.73), only two studies provided SSQ data after ACD use that limited the power of the analysis to detect small effects. This speculative analysis suggests that the SSQ is a disease-specific measure that is sensitive to the impact of both CROS and restorative devices, such as CIs, on HRQoL in SSD.

The review did not identify any validated instruments specifically designed for measuring HRQoL in those with SSD. Instruments such as the SSQ and the APHAB do include questions about many listening abilities that are impaired as a result of SSD and which may be aided by the use of an assistive device. However, they do not distinguish between sounds located on the impaired and non-impaired sides. The position of a sound relative to the impaired ear is a factor that has been found to influence the level of difficulty experienced by patients with SSD and which they can rate as more important to resolve than difficulties with understanding speech in noise and in localising sounds [McLeod et al., 2008]. While the development and validation of a specific instrument for measuring HRQoL in SSD would be useful to the field, existing instruments such as the SSQ are an appropriate choice when evaluating the impact of hearing-assistive devices whose primary purpose is to aid speech perception in noise and sound localisation.

Conclusions

A synthesis of the current evidence for the impact of hearing-assistive devices on HRQoL in adults with SSD suggests that, when measured using disease-specific instruments, the average effect of ACDs on HRQoL is small and BCDs have a medium effect. CIs are associated with a larger effect size, but one which should be considered a medium effect due to being derived from within-subject comparisons of HRQoL before and after implantation. The review identified the SSQ as a disease-specific instrument that is sensitive to the impact of CROS and restorative hearing-assistive devices on HRQoL. Few studies have measured the impact of these devices using generic instruments, but data from those that have suggest that generic instruments such as the HUI3 are sensitive to changes in the HRQoL of adults with SSD.

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