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REVIEW ARTICLE

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Hearing-impaired population performance and the effect of hearing interventions on Montreal Cognitive Assessment (MoCA): Systematic review and meta-analysis

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Background: Older adults are at high risk of developing age-related hearing loss (HL) and/or cognitive impairment. However, cognitive screening tools rely on oral administration of instructions and stimuli that may be impacted by HL. This systematic review aims to investigate (a) whether people with HL perform worse than those without HL on the Montreal Cognitive Assessment (MoCA), a widely used screening tool for cognitive impairment, and what the effect size of that difference is (b) whether HL treatment mitigates the impact of HL.

Method: We conducted a systematic review and meta-analysis including studies that reported mean MoCA scores and SDs for individuals with HL.

Results: People with HL performed significantly worse on the MoCA (4 studies, N = 533) with a pooled mean difference of −1.66 points (95% confidence interval CI -2.74 to −0.58). There was no significant difference in MoCA score between the pre- vs post-hearing intervention (3 studies, N = 75). However, sensitivity analysis in the cochlear implant studies (2 studies, N = 33) showed improvement of the MoCA score by 1.73 (95% CI 0.18 to 3.28).

Conclusion: People with HL score significantly lower than individuals with normal hearing on the standard orally administered MoCA. Clinicians should consider listening conditions when administering the MoCA and report the hearing status of the tested individuals, if known, taking this into account in interpretation or make note of any hearing difficulty during consultations which may warrant onward referral. Cochlear implants may improve the MoCA score of individuals with HL, and more evidence is required on other treatments.

KEYWORDS
cochlear implant, hearing aid, hearing difficulty, hearing disorder, hearing impair*, hearing loss, MeSH subject headings, MoCA, Montreal Cognitive Assessment

1 | INTRODUCTION

Dementia is a syndrome involving deteriorations of multiple higher cortical functions, including memory, thinking, orientation, comprehension, calculation, learning capacity, language, and judgement.[1] The number of dementia cases population is predicted to increase in the next decades due to the increase in ageing population.[2] The largest incidence of dementia occurs in individuals aged over 65,[3] and one in three people in this age group have hearing loss.[4,5] Recent studies suggest that age-related hearing loss is associated with accelerated cognitive decline and higher risk of developing dementia.[6,7] Moreover, a similarly significant association has also been found between cognitive decline and self-reported hearing difficulties in older adults without standardised hearing tests.[8]

Routine cognitive screening tools rely on oral administration of instructions and stimuli and implicitly assume normal hearing. Individuals with hearing loss may, however, make frequency-specific phoneme errors that correspond to their audiometric profile, and thus fail elements of the test due to their poor hearing rather than cognitive impairment, potentially leading to false-positive results when screening for potential cognitive impairment.[9] This may lead to an unnecessary over-onward referral for cognitive assessment. A recent cross sectional study found an association between pure tone audiometry and mini-mental state examination score, possibly accounted for by an MMSE test item that assesses repetition of an auditorally presented sentence.[10] Therefore, the interpretation of cognitive screening test results among hearing loss older adults should be done carefully.

The Montreal Cognitive Assessment (MoCA) is a brief and validated orally administered cognitive screening test that probes a number of cognitive functions, including orientation, language, working memory, delayed memory, executive function and visuospatial abilities. The MoCA is one of the most widely used tools in research and clinical practice to screen for cognitive impairment. It is available in several languages.[11] Moreover, it has been proven to be more accurate than other measures, such as the Mini-Mental State Examination (MMSE), in detecting mild cognitive impairment.[12]

For both clinical and research purposes, it is important to determine to what extent cognitive screening tests that assume normal hearing might be introducing a bias. A meta-analytic review was conducted for this purpose, focused on the MoCA. The objectives of this meta-analysis review are to determine (a) the effect size of the impact of hearing loss on MoCA scores, and (b) whether hearing loss treatment (of hearing amplification or implantable devices) mitigates this impact. The overarching aims of the review were to summarise the existing research on the presence and extent of a possible bias in the cognitive screening for people with hearing loss, to inform future research on the impact of hearing loss treatment on cognitive screening and to elucidate the most effective methods of cognitive screening irrespective of hearing ability.

2 | METHODS

This review follows guidelines provided by the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines[13] and the protocol is registered on the PROSPERO database under the identification code CRD42018112284.

Key Points

- People with hearing impairment score significantly lower than individuals with normal hearing on the standard orally administered MoCA.
- Clinicians should consider listening conditions when administering the MoCA and report the hearing status of the tested individuals, if known, taking this into account in interpretation or make note of any hearing difficulty during consultations which may warrant onward referral.
- Cochlear implants may improve the MoCA score of individuals with hearing impairment, and more evidence is required on other treatments.

2.1 | Search strategy

The P - patient, problem or population; I - intervention; C - comparison, control or comparator; O - outcome (PICO) framework was used to optimise database searching.[14]

The two questions of this review in PICO format are.

PICO 1

- P: Individuals with Hearing Loss (HL)
- I: The Montreal Cognitive Assessment (MoCA)
- C: Comparison of MoCA performance between individuals with HL and individuals with Normal Hearing (NH)
- O: Hearing thresholds and MoCA outcomes across different levels of Hearing Loss (HL)

PICO 2

- P: Individuals with Hearing Loss (HL)
- I: The Montreal Cognitive Assessment (MoCA)
- C: Comparison of unaided MoCA performances of individuals with HL to their performance when aided by the use of a Hearing Aid (HA) or Cochlear Implant (CI)
- O: Hearing thresholds and the results of MoCA test/retest

PICO 1 outlines the comparison of MoCA scores between those participants with hearing loss and those with normal hearing cohorts within the same study.

PICO 2 outlines the comparison of the unaided performances of individuals with hearing loss to the performances of the same individuals post-intervention that included hearing aids or cochlear implant.

We searched SCOPUS, MEDLINE (Ovid) and PUBMED, and the results of these searches were augmented by the secondary search of the bibliographies. Keywords included: "Montreal Cognitive Assessment," "MoCA," "hearing loss," "hearing impair,*" "hearing difficulty," "hearing disorder," "hearing aid," and "cochlear implant," as well as MeSH subject headings such as hearing loss. The database search was augmented with by bibliography searches, followed by a screening of all of the titles and abstracts, identification of strong candidates, and review of full texts (see Tables S1-S3 in Data S1).

The search took place on the 23rd of April, 2019. The titles and abstracts were then screened, followed by review of the full texts of candidate papers for their adherence to inclusion and exclusion criteria. At this point, quality analyses were performed independently by two researchers (NU and KW using the QUADAS-II scale) and compared to create a consensus about which studies should be considered for the meta-analysis (see Table S4 in Data S1). There were no limitations on the initial years of publication, though it is important to note that the MoCA was only recently validated by a study in 2005.[11]

We included studies that reported mean MoCA scores (including SDs) of participants with hearing loss for the meta-analysis. No studies were excluded on the basis of geographic location, provided that there was a validated version of the MoCA that suited that population. Studies were excluded when they used the MoCA as a baseline test of cognition, but did not report scores, or when none of the groups reported were composed of participants with hearing loss. All journals and conference proceedings were considered for inclusion. Finally, studies without an English translation were excluded following unsuccessful author contact.

For evaluating the quality of included papers, ROBIN-I[15] and Cochrane risk of bias assessments[16] were conducted by the first and second authors independently, and differences were resolved by consensus after discussion with the senior author. Studies were examined for the following types of bias: selection bias, performance bias, detection bias, attrition bias, reporting bias, education bias and test-retest bias.[17] In the context of this review, educational bias refers to disproportionate levels of education between groups and test-retest bias refers to the proximity of MoCA assessments within a study.

2.2 | Data analysis

Means and SDs of MoCA scores were recorded, categorised and analysed using Review Manager (RevMan) computer programme version 5.3 recommended by the Cochrane collaboration.[18] The first outcome was the difference in mean MoCA scores of participants with hearing loss compared to normal hearing participants with random-effect model. Due to concerns about potential correlation bias, outcome 2 comparing scores of individuals with HL in unaided and aided conditions was also analysed with a correlated measure analysis of pooled prevalence via inverse variance calculations, in addition to the standard continuous data calculation used for the first outcome. First, the mean difference and SE were calculated for each study using the mean, SD, and number of participants (n) inputs provided. Then, the information was synthesized as a pooled estimate via the Generic Inverse Variance data option.

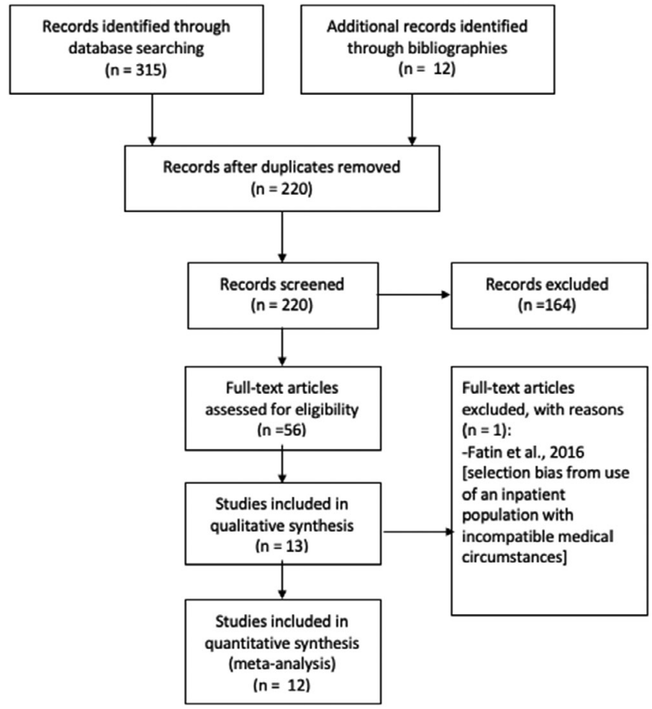

FIGURE 1 Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram

Heterogeneity interpretation used guidelines from the National Institute of Health (NIH) that suggest that an I^2 score >50% indicates possible heterogeneity, and an I^2 score >75% indicates a considerable probability of heterogeneity, prompting further investigation.[19,20]

3 | RESULTS

The publication years of the articles identified in this review span between 2015 and 2018. The workflow of the systematic literature review is summarised in Figure 1.[13] Thirteen studies were identified after full-text review, however one article[21] was eliminated after qualitative analysis, due to confounding variables, unclear outcome measures and weak study design. Of the 12 studies analysed, eight followed observational design and four followed experimental design.

The qualities of papers are assessed and presented in Tables S5 and S6 in Data S1. In total, there were 950 participants across all 12 studies included in the review. Though the majority of participants were over the age of 60, one study included a cohort of younger participants (mean age 18 ± 0.3 years) in their analysis.[22] Studies varied in their inclusion of participants with different hearing ability from normal hearing profiles to profound hearing loss. Studies also varied in their inclusion of participants with a history of hearing augmentation use. Basic information about the studies of PICO1 and two including their inclusion and exclusion criteria were described in Tables 1 and 2.

TABLE 1 Overview of PICO 1 study information

	Patient selection	Inclusion/Exclusion criteria	Degree of HL in better ear, n (%)		Demographic info		
Dupuis et al[23]	Participants were recruited from existing volunteer pools at the University of Toronto, from the Canadian Hearing Society office in Toronto, and from advertisements placed in local newspapers	IC: ≥18 y old, living in the community EC: NR	Normal (<25 dB HL) Mild-Mod Severe (25-70 dB HL)	165 (55%) 136 (45%)	G1 n: 165 YE: 16.9 ± 0.3 Age: 69 ± 0.5 M:31% F: 69%	G2 n: 136 YE: 15.2 ± 0.3 Age: 73.6 ± 0.6 M: 43% F: 57%	
Dupuis et al[22]	Older participants were recruited from the Dupuis et al[23] study a year prior, recruitment was based on that existing volunteer pool and they each received an honorarium. Younger participants were university students and received course credit	IC: Self-reported their health as "good" or better, learned English before the age of 5 y in a country where English is the dominant language EC: NR	Normal (<25 dB HL) Mild-Mod Severe (25-70 dB HL)	40 (66%) 20 (34%)	G1 n: 20 YE: 12.9 ± 0.3 Age: 18.8 ± 0.3 M: 20% F: 80%	G2 n: 20 YE: 16.1 ± 0.7 Age: 71.4 ± 1.3 M: 35% F: 65%	G3 n: 20 YE: 15.7 ± 0.9 Age: 73.7 ± 1.3 M: 30% F: 70%
Yeok Lim et al[9]	Healthy adults (Singaporean or permanent residents) who attended the National University Hospital ENT outpatient clinic between August 2016 and January 2017	IC: ≥55 y old, had undergone hearing assessment, were able to speak or understand English or Mandarin EC: Diagnosed with severe vision problems or dementia, use of HAs within the past 5 y	Normal (<25 dB HL) Mild (26-40 dB HL) Mod. (41-55 dB HL) Mod. Sev. (56-70 dB HL) Severe (71-90 dB HL)	28 (24.6%) 44 (38.6%) 26 (28.2%) 10 (8.8%) 6 (5.3%)	n: 111 YE: 10.3 ± 4.5 Age: 67.2 ± 8.0 M: 48% F: 52%		
Lin et al[24]	Participants recruited from the Adult Cochlear implant programme	IC: ≥60 y old EC: Family history of dementia or neurological disease, failing score on the Personal Health Questionnaire, Activities of Daily Living Questionnaire by Proxy, or the Alzheimer's Society of Canada screening questionnaire for primary care physicians	Normal (<25 dB HL) Severe (71-90 dB HL)	103 (68%) 49 (32%)	G1 n: 103 YE: 15.65 ± 2.25 Age: 68.41 ± 6.17 M: 28% F: 72%	G2 n: 49 YE: 15.04 ± 2.40 Age: 70.23 ± 6.74 M: 47% F: 53%	
Saunders et al[25]	Recruited between June 2015 and March 2016 from a database at the National Centre for Rehabilitative Audiology Research (NCRAR)	IC: Fluency in English, aged 50-89 y old, symmetrical hearing EC: Asymmetrical hearing, inability to complete test protocol	Normal (<25 dB HL) Mild-Mod Severe (25-70 dB HL)	19 (31%) 42 (69%)	G1 n: 19 Age: 63.2 ± 6.2 M: 60% F: 40%	G2 n: 20 Age: 70.1 ± 6.3 M: 65% F: 35%	G3 n: 22 Age: 69.6 ± 5.6 M: 86% F: 14%

Abbreviations: F, female; G, group; M, male; n, number of participants; YE, years of education.

TABLE 2 Overview of PICO 2 study information

	Patient selection	Inclusion/Exclusion criteria	Degree of HL in better ear, n (%)			Demographic info			
Ambert-Dahan et al[26]	NR	IC: Native French speaking cochlear implantation candidates with severe to profound post-lingual progressive SNHL EC: History of neurological, vision, or psychiatric illness		Bilateral severe to profound HL (≥ 70 dB HL)	18 (100%)	n: 18 Age: 64 ± 3.5 M: 62% F: 38%			
Castiglione et al[27]	Participants were recruited from a list of hearing-impaired patients identified via a hospital case file review	IC: ≥65 y old, mild to profound HL examined between July 2012 and April 2015 EC: NR	C	Moderate to severe HL (41-70 dB HL)	75 (60%)	GC n: 75	GD n: 15	GE n: 15	GF n: 20
			D	Mild to moderate HL (26-40 dB HL)	15 (12%)	Age: range 65-89, median 76	Age: range 67-85, median 75	Age: range 65-75, median 71	Age: range 65-89, median 74
			E	Profound HL (≥90 dB HL)	15 (12%)	M: 60% F: 40%	M: 60% F: 40%	M: 53% F: 47%	M: 45% F: 55%
			F	NH	20 (16%)				
Saunders et al[25]	Recruited between June 2015 and March 2016 from a database at the National Centre for Rehabilitative Audiology Research (NCRAR)	IC: Fluency in English, aged 50-89 y old, symmetrical hearing EC: Asymmetrical hearing, inability to complete test protocol	1	NH	19 (31%)	G1 n: 19	G2 n: 20	G3 n: 22	
			2	Mild to severe HL (25 dBHL- 70 dB HL)	20 (33%)	Age: 63.2 ± 6.2	Age: 70.1 ± 6.3	Age: 69.6 ± 5.6	
			3	Mild to severe HL (25 dBHL- 70 dB HL) [+HAs]	22 (36%)	M: 60% F: 40%	M: 65% F: 35%	M: 86% F: 14%	

Abbreviations: F, female; G, group; M, male; n, number of participants; NH, normal hearing; YE, years of education.

TABLE 3 Data extraction table

	n	Groups	MoCA version	# of MoCAs	Time between MoCAs	MoCA Means ± SDs
Ambert-Dahan et al[26]	18	N/A *All have severe-profound post-lingual HL*	7.1 (French) (modified with adapted visual presentation)	2 (Pre/Post-Op)	12 mo.	Pre-op: 25.11 ± 3.46 Post-op: 27 ± 2.63
Castiglione et al[27]	65	C: long-term unilateral HA users, mod-severe HL (15) D: untreated HI elderly w. mild-mod HL (15) E: CI users, severe-profound HL (15) F: control group, NH (20)	7.1	C, D, F: 1 E: 2 (Pre/Post-Op)	D, F: N/A C = 12-24 mo. E = 12 mo.	C: 23.71 D: 19.89 E: Pre-implant = 25.70 ± 3.08, Post implant = 27.20 ± 3.72 F: 25.78
Claes et al[28]	26	N/A *All have severe-profound bilateral HL*	7.1	2 (Pre/Post-Op)	Mean of 17 d	Pre-op: 22.3 ± 4.1 Post-op: 22.7 ± 4.5
Dupuis et al[23]	301	G1: NH (163) (NV: 147, VL: 16) G2: HL (134) (NV: 112, VL: 22)	7.1; but scored three different ways	1 (baseline)	N/A	G1: 26.2 ± 2.6 G2: 24.3 ± 2.9
Dupuis et al[22]	60	G1: YA w. NH (20) G2: ≥ 70 y/o, NH (20) G3: ≥ 70 y/o, HL (20)	7.1, 7.2, 7.3 (modified noise conditions)	3	NR	**Means + SDs averaged across all noises conditions** *(Did not include in the meta-analysis since different MoCA versions and participants were from Dupuis2015 study)* G1: 26.2 ± 2.0 G2: 23.4 ± 2.5 G3: 22.9 ± 2.8
Fatin et al[21]	71	*All have HL, randomised into A or B* A: HL (33) B: HL (38)	7.1 (Malaysian)	2 (w + w/o HAs)	24-48 h	Excluded from data analysis due to poor quality
Galster et al[29]	61	N/A *All have mild-severe HL*	7.1	1 (baseline)	N/A	26.32 ± 2.31
Karawani et al[30]	35	*All have mild-severe HL* G1: Experimental, given HAs for 6 mo. G2: Control, ⊘ HA	7.1	1 (baseline)	N/A	G1: 26.36 ± 1.6 G2: 25.23 ± 2.5
Karawani et al[31]	32	*All have mild-severe HL* G1: Experimental, given HAs for 6 mo. G2: Control, ⊘ HA	7.1	1 (baseline)	N/A	G1: 26.72 ± 1.77 G2: 25.24 ± 2.45
Lim et al[9]	114	N/A 24.6% = NH, 75.4% = HL	7.1 (Singaporean)	1 (baseline)	N/A	23.6 ± 4.1 **Mean scores of all participants, HL and NH** *(can't include in meta-analysis)*
Lin et al[24]	152	G1: NH (103) G2: HL (49) [severe]	HI-MoCA 7.1	2	6-8 mo.	G1: HI-MoCA = 26.66 ± 2.642, MoCA = 27.14 ± 2.005 G2: HI-MoCA = 26.84 ± 2.579, HI-MoCA = 26.493 ± 2.639
Saunders et al[25]	42	G1: NH (19) G2: HL ⊘ HA (19) G3: HL-HA (22)	7.1 7.3	2 (aided vs unaided	Same day, different versions	G1: 25.9 ± 1.8, 26.1 ± 2.3 G2: 24.8 ± 2.1, 24 ± 2.5 G3: 22.5 ± 2.9, 23.1 ± 3.5
Shen et al[32]	28	*All have mild-mod, SNHL	7.1	1	N/A	26.35 ± 2.49

Abbreviations: HA, hearing aid; HL, hearing loss; N/A, not applicable; NH, normal hearing; NR, not reported; NV, normal vision; VL, vision loss; YA, young adult.

The number of times the MoCA assessments were conducted, and the duration of time in-between assessments varied, with some studies only collecting baseline data and others conducting pre and post-surgical assessments as much as a year apart (described in Table 3). Blinding and randomisation were limited due to the nature of the research objectives and the inclusion of a high percentage of participants with visible hearing augmentation.

3.1 | PICO 1. Comparison of MoCA scores in hearing loss population and normal-hearing population

We included four papers in PICO 1 analysis. The details of each paper were described in Table 1. The random effect differences and 95% confidence intervals for the difference of MoCA score among individuals with hearing loss and normal hearing controls within the same study was analysed and demonstrated in Figure 2. The mean MoCA scores among the hearing loss group were worse than their normal hearing peers in all included studies. The mean difference of MoCA between the two cohorts was −1.66 (95% confidence interval −2.74 to −0.58).

Following the identification of the high I^2 score (78%), the studies in outcome one were re-examined for significant sources of heterogeneity. Through running a sensitivity analysis, two potential sources of heterogeneity were identified from the Lin et al. study (abnormally high MoCA scores from strict inclusion criteria and use of the visually based Hearing-Impaired MoCA).[24] However, after the Lin study was excluded from the analysis, the I^2 decreased by only 11% and there was no significant change in the overall effect (mean difference = −2.08, 95% confidence interval −3.19 to −0.97 in Figure S1 in Data S1).

3.2 | PICO 2. Comparison of MoCA scores in pre- vs post- audiological intervention

We included three papers in PICO2 analysis. The details of each paper were described in Table 2. Overall, there was no significant difference between the pre- and post-auditory intervention MoCA score (mean difference = −0.71, 95% confidence interval – 2.57 to 1.16) as shown in Figure 3. However, Ambert-Dahan et al[26] and Castiglione et al[27] were pre and post cochlear implantation studies unlike Saunders et al[25] which used hearing aids. Sensitivity analysis was performed on cochlear implant papers only. The I^2 decreased to 0 which indicated homogeneity and the mean difference of the pre and post-implantation MoCA score was significantly different by −1.73 (95% confidence interval −3.28 to −0.18). This indicated improvement of the MoCA score after cochlear implantation, whereas no improvement was found for MoCA score after hearing aid use with a mean difference of 0.8 (95% confidence interval −0.63 to 2.23) from Saunders et al 2017 study.

4 | DISCUSSION

4.1 | PICO 1: MoCA among hearing loss population

We found that the hearing impaired samples had a statistically significant mean disparity of up to 1.66 points in their MoCA scores compared to the normal-hearing samples. This is a clinically significant difference since the Minimal Clinically Important Difference (MCID) of MoCA has previously been estimated to be 1.22.[33]

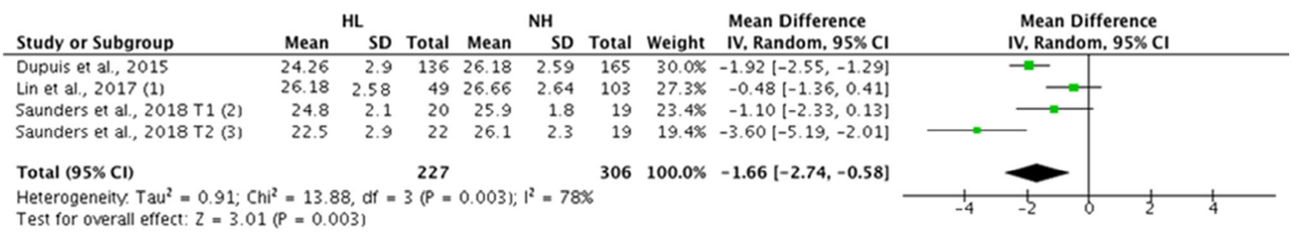

FIGURE 2 Forest plot comparing Montreal Cognitive Assessment (MoCA) score of participants with hearing loss and normal hearing (Random effect model) [Colour figure can be viewed at wileyonlinelibrary.com]

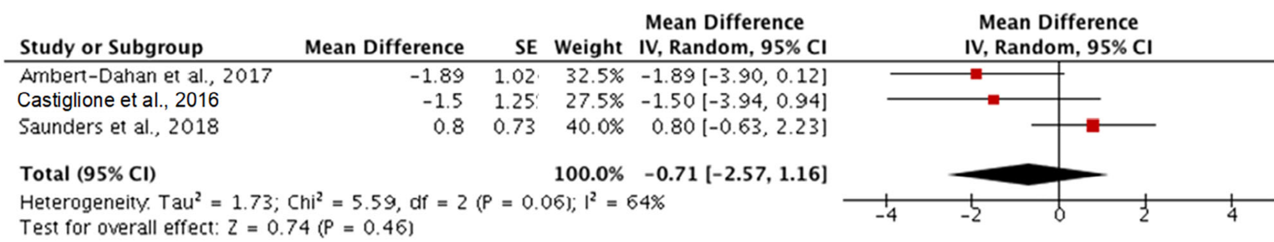

FIGURE 3 Forest plot comparing scores of HI individuals in unaided and aided conditions (Random effect model) [Colour figure can be viewed at wileyonlinelibrary.com]

The lower score on MoCA among the hearing loss cohort than those with normal hearing still does not elucidate whether this is an effect of the traditional oral testing method or indicative of actual cognitive impairment. From the two included papers[9,23] which detailed the breakdown of the MoCA memory scores, some words had a significantly greater percentage of error depending on the frequency characteristic of the words, which coincide with the participants' hearing loss frequencies. Consequently, target words may play a role in inaccurate test scores among the hearing loss population. However, it was not possible to conduct a meta-analysis to assess this since the two papers used different MoCA versions. Therefore, this effect should potentially be considered when interpreting MoCA in clinical consultation and should be a subject of future research.

These findings align with the previous research that older individuals with hearing loss are more likely to generate false-positive results in cognitive screening assessment.[9] When conducting traditional cognitive screening tests such as with MoCA, the audiological status of the participant may interfere with the result. It is also possible (although not directly assessed in this meta-analysis) that ambient noise may also affect findings,[22] since the hearing impaired population cannot attend to the instructions/targets nor filter out ambient noise unlike their normal hearing peers,[34] which may has an additive effect when combined with the attentional difficulties inherent in cognitive impairment population.[35] One potential amelioration for this would be to conduct cognitive assessments in a very quiet environment and use amplification when this is warranted. Another would be to use tests designed to assess cognition through other modalities than auditory input. Such tests would also be useful in untangling the mechanism by which hearing impairment is associated with cognitive deficits. Several initial adaptations of existing cognitive tests have been made for this purpose, however, the tests first need to be validated prior to incorporation in clinical guidelines for healthcare professionals.[36] Early work has already suggested that such deficits are not entirely accounted by purely sensory factors, and may arise due to several different postulated mechanisms such as long term effects of deprivation of input to the brain, effects of social isolation and depression.[37,38]

Current routine audiological assessments do not include cognitive screening, while standard cognitive screening measures are not adapted for individuals with hearing loss. Early identification of cognitive impairment in hearing-impaired individuals is likely to be important since there are studies showing that cognition may be remediated to an extent by aural rehabilitation.[6,37] These factors underscore the importance of using effective cognitive screening measures for individuals with hearing loss, as well as the potential value of integrating such screenings into routine audiological assessments for individuals over the age of 60.

Cognitive screening for older adults with hearing loss should be done carefully. Any individual with possible impairment shown on the screening test should be referred for comprehensive neuropsychological evaluation rather than formulating any clinical decision solely based on the MoCA screening results.

4.2 | PICO2: MoCA improvement after intervention

There was a significant improvement of MoCA score by 1.73 points after cochlear implant auditory intervention only. The single study using hearing aids by Saunders et al 2017 that was included in our meta-analysis did not find a significant difference in performance between the aided and unaided conditions of MoCA. This may be due to the fact that in the study, participants were assessed on the MoCA twice within the same day (once with hearing aids and once without). Results could potentially differ in a more longitudinal approach, as in the CI studies, where the time interval between assessments was 12 months at least. This longer time interval may be required for post auditory remediation effects and benefits, in terms of improved patient self-efficacy and social function[38] and of brain plasticity[39] to be established, which may have a positive impact on cognition. Alternatively, the difference in findings between the two CI studies vs the single HA study may be attributed to the degree of the HL, which was greater in the CI studies. This could have influenced the unaided baseline MoCA scores to a greater extent perhaps in part due to the greater hearing restoration given by cochlear implantation when compared with hearing aids. Although the administration mode of the MoCA was kept constant throughout each study, the mode in Saunders et al 2017 was traditional live-voice for hearing aid users, whereas Ambert-Dahan et al[26] used a visual modified MoCA for cochlear implant users.

Overall, the result of PICO 2 emphasizes the importance of hearing intervention in improvement of MoCA performance. Moreover, severe untreated hearing loss can greatly affect older adult communications with clinicians which may potentially also affect their performance during consultations. Therefore, if any hearing difficulty was suspected during a cognitive assessment, prompt onward referral for comprehensive hearing assessment along with appropriate hearing intervention should be encouraged. Since older adults with cognitive problems may not always report their hearing difficulties,[40] their carers and healthcare providers should be mindful of this in order to offer early intervention.

4.3 | Strengths, limitations and need for future research

The main limitation of this meta-analysis is that we were able to identify only a few studies that met criteria for inclusion, so that while the quality of these studies was determined to be high, the sample size limits the robustness of our findings.

More research is required to examine the impact of possible moderating factors of the association between hearing loss and cognitive testing scores, including from conditions known to be linked to both hearing loss and cognition, such depression.[41,42] Methodological factors, such as the lexical frequency of the words used as stimuli, may also impact the association,[9,23] but we were not able to study these potential effects in our meta-analysis as different MoCA versions had been used.

Moreover, the impact of combined hearing and cognitive impairment in older adults if any, was not explored in this meta-analysis due to lack of available studies. Further studies targeting older adults with these dual impairments would be needed to explore this effect.

5 | CONCLUSION

Results from the present meta-analysis indicate that the people with hearing loss have significantly lower MoCA scores than the normal-hearing population by 1.66 points, which is a clinically significant effect. Hearing intervention such as with cochlear implantation could help to improve the MoCA score of the hearing loss population, however the evidence to support this is based on a limited number of subjects and thus weak.

Our work suggests that clinicians should be mindful of any potential impact of known or suspected hearing loss when interpreting traditional MoCA scores, and should optimise listening conditions when administering the MoCA to reduce this bias.

Further research is required to understand the relationship between hearing loss and cognition, as well as whether a MoCA specifically developed for individuals with hearing loss could eliminate the differences in performance due to hearing loss while remaining a valid instrument to detect cognitive impairment.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

N.U. and K.W. is the main author of this paper. K.W. conducted literature search. K.W. and N.U. conducted the systematic review. D.E.B., J. S., S.G.C. contributed to the manuscript write up. All authors read and approved the final manuscript.

ETHICS STATEMENT

This systematic review protocol is registered on the PROSPERO database under the identification code CRD42018112284.

Ethical approval is exempted for systematic review studies.

DATA AVAILABILITY STATEMENT

Data derived from public domain resources as stated in the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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