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Research Article

# Evaluation of Diagnostic Measures in Veterans With Self-Perceived Hearing Handicap Despite Normal Audiometric Thresholds: A Rapid Scoping Review

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ABSTRACT

**Purpose:** This rapid scoping review examined clinical test measure literature among veterans with self-perceived hearing handicap with normal audiometric threshold configurations (SPHH-NA) and those with normal audiometric thresholds and no self-perceived hearing handicap to determine which tests differentiate these groups.

**Method:** A rapid scoping review in the PubMed and CINAHL databases was completed. Articles included met the following criteria: experimental studies, written in English, with full online article access, participants who were U.S. military members or veterans reporting SPHH-NA completing at least one diagnostic test. Effect sizes from the articles meeting the inclusion criteria were calculated using Hedges' *g* measure of effect size to determine the clinical significance.

**Results:** Eleven of an initially identified 1,836 articles met the inclusion criteria. Twenty-seven test measures were completed across the 11 studies. Fifteen test measures found a significant difference between groups in at least one study. Some studies using the same test measures did not find a significant difference. Twelve other test measures did not show any significant differences. Self-report questionnaires were the only measures to find large effect sizes across multiple studies. Five speech-in-noise tests were administered with only one instance finding a large effect size.

**Conclusions:** Traditionally, readily available audiometric tests have been applied to those with SPHH-NA. The results of this study support the need to carefully consider what underlying mechanisms may differentiate these populations. Improved diagnostic approaches targeting higher level processing may support targeted treatments. Given the large number of measures evaluated that do not show any differences, we recommend changing our approach for future research to consider factors that extend beyond only evaluating the auditory system.

Audiologists are defined through their scope of practice as independent health care providers who are uniquely trained to provide assessment, prevention, and treatment of auditory disorders (American Academy of Audiology, 2023; American Speech-Language-Hearing Association, 2018). Assessments may include measures of both peripheral and central hearing ability. Based on the findings from assessments, the audiologist counsels the patient regarding the results and appropriate treatment approaches. For most individuals with measurable hearing loss through conventional testing, an explanation of degree, type, and configuration of hearing loss along with word recognition ability and expected impact on daily activities is provided to the patient. The audiologist makes treatment recommendations that may include amplification, assistive technology, aural rehabilitation, communication strategies, or referrals to other health care professionals for further evaluation, if warranted.

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This approach works well when utilized as a clinical decision-making model for those with measured hearing loss, as a plethora of evidence exists to support the current diagnostic battery and treatment approach for this population. However, a small portion of the population seeking hearing health care services from audiologists include individuals who perceive hearing difficulties despite having no measurable hearing loss (Hind et al., 2011; Parthasarathy et al., 2020; Spehar & Lichtenhan, 2018). Although this can be considered a fundamentally different population (no threshold-based hearing loss), the same assessment approach and treatment recommendations are commonly applied (Hotton & Gagné, 2022; Turner et al., 1984). The audiologist's approach of completing diagnostic measures and recommending treatments with which they are comfortable despite the absence of research to support accurate diagnosis and positive treatment outcomes for a new population is consistent with other health care disciplines in which the approach is based on familiarity rather than evidence (Levinson et al., 2015).

Adults with no measurable hearing loss reporting difficulties hearing, specifically in noise, have been identified since the 1980s (Narula & Mason, 1988). The naming of this phenomenon was first reported as selective dyacusis and has been labeled with other designations such as idiopathic discriminatory dysfunction, King-Kopetzky syndrome, and obscure auditory dysfunction (Beck et al., 2018; Saunders & Haggard, 1989; Zhao & Stephens, 1996). Today, this term is now commonly classified as hidden hearing loss (HHL) or specifically cochlear synaptopathy when trying to associate the symptoms with a specific site of lesion (Kujawa & Liberman, 2009; Schaette & McAlpine, 2011). The first test battery to diagnose this condition was recommended in 1992 (Saunders et al., 1992). The recommended tests were separated into four categories identified as general tests, psychoacoustic tests, central tests, and personality-related tests. The general tests category included an obscure auditory dysfunction interview, the Institute of Hearing Research hearing questionnaire, and pseudo-free-field speech-in-noise test. The psychoacoustic tests included pure-tone audiometry, binaural masking level difference at 500 Hz, otoacoustic emissions, and noise emission rating. The central tests included word monitoring in sentences test, audiovisual adaptive sentence test, and a dichotic listening test. The personality-related tests included Crown-Crisp Experimental Index and PS discrepancy (PS-DIS), which measures the degree of misjudgment in hearing ability by subtracting an individual's self-assessed performance speech reception threshold in noise (SSRTN) from the individual's actual performance of speech reception threshold in noise testing (PSRTN).

Although HHL, auditory processing disorder (APD), and self-perceived hearing handicap (SPHH) are sometimes used interchangeably, it is important to distinguish that SPHH/HHL typically describe symptoms acquired from multiple factors, such as specific events or comorbidities, whereas APD is classified as a developmental diagnostic category that can be present in both the pediatric and adult populations (American Academy of Audiology, 2010; Plack et al., 2014; Rawool, 2016). For the purposes of this article, we will be referring to this phenomenon as self-perceived hearing handicap with normal audiometric threshold configurations (SPHH-NA), which captures the essence of the patient complaint without presupposing specific test results or site of lesion.

Approximately 10% of patients seeking audiology services have normal hearing thresholds (Parthasarathy et al., 2020). In the SPHH-NA population, individuals may have experienced a clinically significant shift in audiometric thresholds but still are classified as having hearing within normal limits (Saunders & Haggard, 1989). Testing beyond the standard audiometric measures has been recommended, but no formal test battery has been adopted by audiologists. Anecdotally, clinicians working with this patient population may include less common audiological tests such as high-frequency audiometry, distortion product otoacoustic emissions (DPOAE) testing, auditory brainstem response (ABR) testing, speech-in-noise tests, and tests to evaluate auditory processing disorders (APD); however, lengthy test batteries can be problematic due to time constraints and/or patient fatigue (Dillon et al., 2012). In many cases, reimbursement may not be forthcoming for tests beyond a comprehensive hearing test given these patient complaints.

Currently, there are no universally accepted clinical guidelines for referral, assessment, and treatment recommendations in the SPHH-NA population. Recent research suggests that some commonly used audiology tests have high classification accuracies in determining the appropriateness of referral for a full auditory processing disorder assessment (Cancel et al., 2023). It is reasonable to expect an audiologist to complete the standard test measures in this patient population if the patient is reporting difficulties that mimic the same complaints as individuals with measured audiometric hearing loss. Despite this clinical approach, most evidence suggests that assessments completed by audiologists in this population including pure-tone audiometry, extended high-frequency pure-tone audiometry, speech testing in quiet, otoacoustic emissions, electrocochleography, and speech recognition in noise without temporal distortion are not sensitive in differentiating those with self-perceived hearing handicaps and normal audiometric configurations (Barbee et al., 2018) versus individuals without SPHH-NA. While audiological test measures are not sensitive in identifying abnormalities in this patient population, self-report questionnaires support the patient complaints (Barbee et al., 2018).

SPHH-NA is a phenomenon of great interest to military and Department of Veterans Affairs (VA) audiologists. There are known links between posttraumatic stress disorder (PTSD) and SPHH-NA, traumatic brain injury (TBI) and SPHH-NA, and noise exposure and SPHH-NA in current and former military service members (Jedlicka & Zhen, 2023; Koebli et al., 2020; Plack et al., 2014). Currently, over 3 million veterans receive compensation benefits for auditory-related disorders (hearing loss and/or tinnitus) and over 1 million veterans receive compensation benefits for PTSD (U.S. Department of Veterans Affairs, n.d.). These large numbers indicate military and VA audiologists are likely required to evaluate and treat individuals with SPHH-NAs.

Currently, VA audiologists are completing auditory processing disorder evaluations without any standard accepted practice of care (Tepe et al., 2020). Recommendations for a proposed minimum test battery for service members and veterans with SPHH-NA were developed to provide a consistent and comprehensive method for evaluation (Tepe et al., 2020). While this recommended protocol was developed using some research that demonstrated significant differences in results for service members and veterans, other research studies evaluating the same measures and population demonstrated a lack of significant difference in test performance among those with SPHH-NA and those without. The inconsistent findings may indicate a lack of reliability among the recommended test measures in the proposed test battery for differentiating this population and targeting treatment.

The purpose of this rapid scoping review was to answer the question "Do any currently implemented assessment measures available to audiologists and reported in the literature show significant differences among veterans and the military population with SPHH-NA compared to those with normal audiometric thresholds and no self-perceived hearing handicap?" This question will be answered by evaluating the literature to determine if any measures confirm the experience of service members and veterans reporting SPHH-NA.

## Method

A rapid scoping review method was used to guide and expedite the research process while providing a comprehensive overview of the published research related specifically to self-perceived hearing handicap with normal audiometry configuration (SPHH-NA) evaluations in the military and veteran populations. This study was exempted from institutional review board (IRB) approval due to being a review of published articles. While traditional scoping reviews include a librarian and multiple study staff to evaluate the identified literature, a rapid scoping review tasks the lead author with the identification and review of literature. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) extension for scoping review (PRISMA-ScR) was used to guide the search and reporting of the literature findings (Tricco et al., 2018).

The literature review was completed in January 2023. The articles were identified in the PubMed and CINAHL databases using key terms related to SPHH-NA in the military and veteran population. The search terms used in this rapid scoping review are shown in Table 1. The PRISMA flow diagram in Figure 1 outlines the process by which articles were excluded from this study. The article review screening was completed solely by the lead author to determine if the articles in the search met the inclusion criteria as shown in Table 2. Article inclusion criteria consisted of peer-reviewed, experimental studies, written in English, with full online article access, including participants who were United States military members or veterans reporting SPHH-NA that completed at least one diagnostic measure. Studies that did not include participant groups of exclusively military members or veterans, those with measured hearing loss, or did not report audiological test measures were excluded.

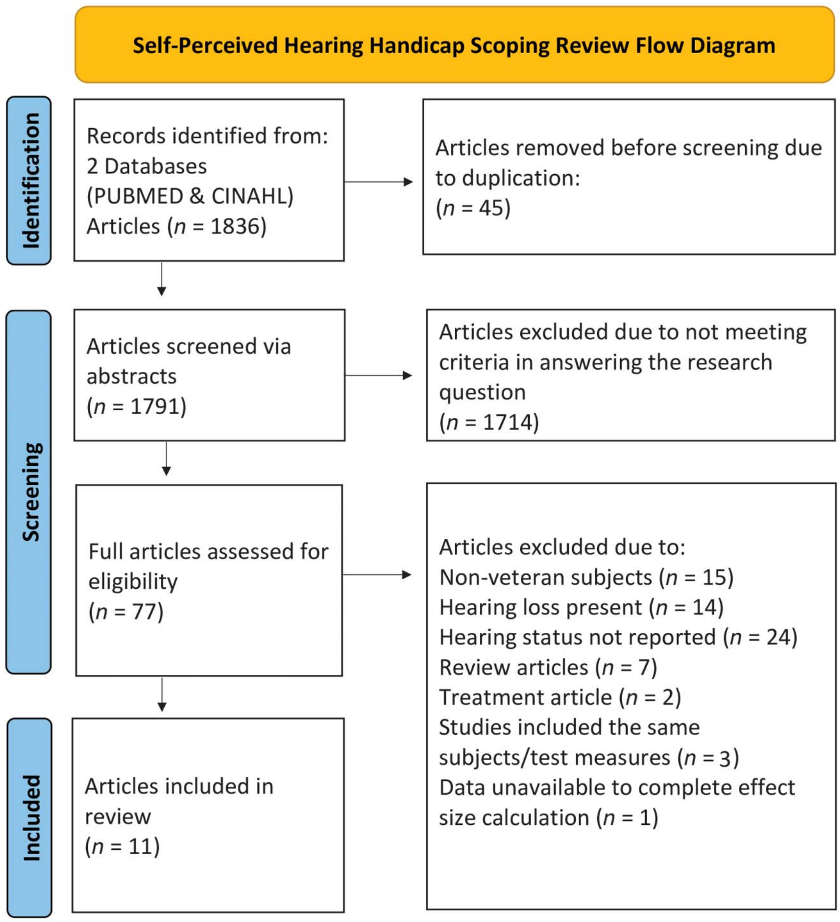
The articles that met the initial screening criteria were entered into a database for documentation. Articles that met the study inclusion criteria through this initial review were read in their entirety. An evaluation of the full article determined if the criteria were met for inclusion into this rapid scoping review.

If an article identified a significant difference between the SPHH-NA group and the control group on any test included in the article, the effect size related to the reported difference was calculated using Hedges'

**Table 1.** Database search terms.

| Rapid review search terms | |
|---|---|
| "veterans and auditory processing disorders" | "veterans and functional hearing deficits" |
| "veterans and hidden hearing loss" | "veterans and hearing in noise" |
| "veterans and auditory dysfunction" | "veterans and normal hearing" |
| "veterans and self-perceived hearing" | "military and auditory processing disorders" |
| "military and functional hearing deficits" | "military and hidden hearing loss" |
| "military and hearing in noise" | "military and auditory dysfunction" |
| "military and normal hearing" | "military and self-perceived hearing" |

**Figure 1.** Preferred Reporting Items for Systematic Reviews and Meta-Analysis flow diagram for article inclusion.



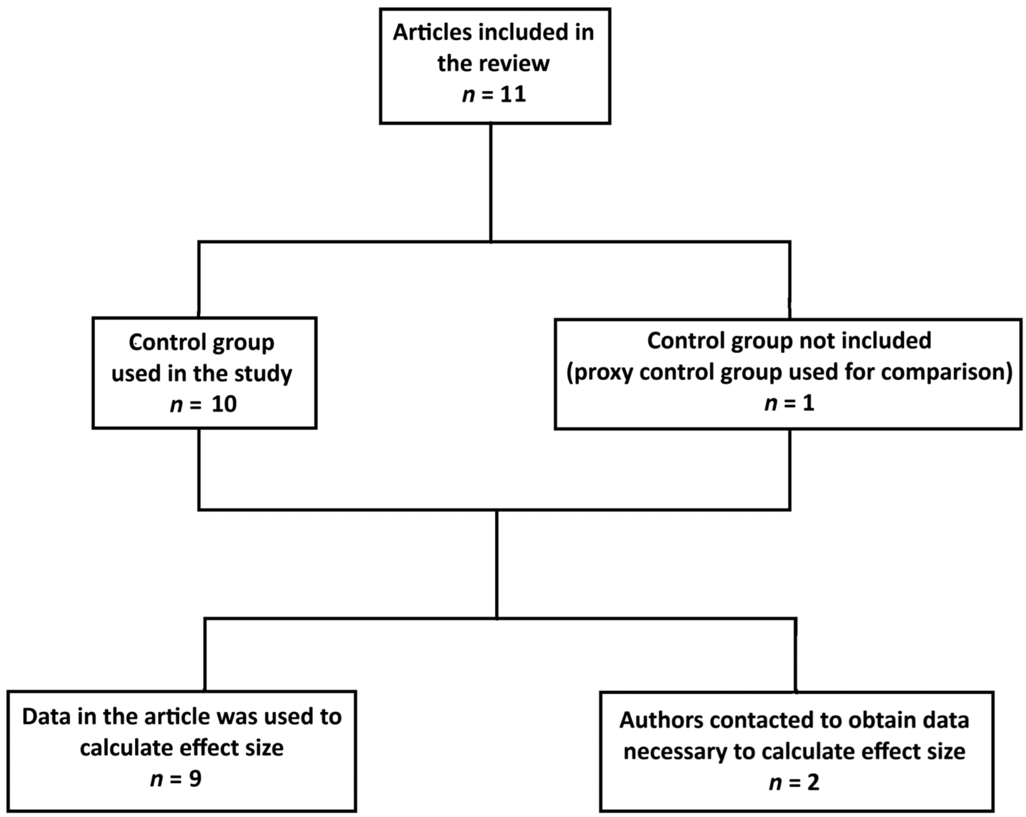

measure of effect size (Hedges' $g$; Hedges, 1981). For articles without a control group, data from other literature evaluating the same measure in a similar aged population without reported hearing difficulties was included for comparison to calculate $g$. In essence, this served as a proxy control group for the study. Only one measure required the use of a proxy group (The North American Listening in Spatialized Noise-Sentences Test [LiSN-S]). Hedges' $g$ was used to calculate the effect size because a number of the studies had small sample sizes. Hedges' $g$ addresses nonnegligible biases for small sample sizes (Lin & Aloe, 2021). If an article did not report a $p$ value, test mean, or test standard deviation, the authors were contacted to obtain the needed information. If we were unable to obtain data for a specific test measure, that measure was not included in the analysis. Two test measures required Freedom of Information requests to obtain the raw data from which the group means and standard deviations were calculated. One study was excluded due to the means and standard deviations not being reported and the data from this study could not be obtained from the author. Figure 2 provides a flowchart highlighting these decisions and activities.

**Table 2.** Article inclusion criteria.

| |
|---|
| Written in English |
| Access to full text of the article |
| Peer-reviewed study with experimental design |
| U.S. military or veteran participants |
| Audiometric thresholds within normal limits |
| Diagnostic measures were included |
| Reported (or obtained from the authors) group means and standard deviations to calculate Hedges' $g$ |

Effect size was selected as the meaningful metric in this review as it allows for a comparison not only between groups but offers insight into the size of the measured effect and therefore potential clinical relevance. A free internet-based effect size calculator was used to calculate the effect size from each measure and therefore determine meaningfulness where a significant difference between groups had been reported

**Figure 2.** Flowchart of control group comparisons.




(Hedges' *g* Calculator; Bobbit, 2021). After the calculation was completed among the measures with significant differences between the groups, the effect sizes were then labeled using the recommended classifiers of negligible (0–0.2), small (0.2–0.5), medium (0.5–0.8), or large (> 0.8; see Table 3; Cohen, 1992).

## Results

The initial search of PubMed and CINAHL databases found 1,836 references for review. Forty-five references were removed due to duplication in the search between databases. The remaining 1,791 article abstracts were screened for inclusion. A total of 1,714 articles were removed due to not meeting the criteria for inclusion. Seventy-seven articles were read in full by the lead author to determine if they met the inclusion criteria. Eleven articles met the inclusion criteria and were included in the full rapid scoping review (see Figure 1). From the 11 included articles, each test measure from each article was placed into one of five categories including questionnaires, electrophysiological tests, speech tests, auditory processing disorder tests, and non-audiological tests. Thirty unique tests were identified and classified in one of the five abovementioned categories. The tests and the corresponding article from which they were reported are shown in Table 4.

**Table 3.** Hedges' measure of effect size classifications.

| Negligible | Small | Medium | Large |
|---|---|---|---|
| 0–0.2 | 0.2–0.5 | 0.5–0.8 | > 0.8 |

The results from each test including mean, standard deviation, and group sample size were entered into a database for analysis. The Hedges' *g* effect size was calculated only in the measures that reported significant differences between the SPHH-NA and normal hearing without SPHH control groups. Fifteen test measures were found to show a significant difference between groups in at least one study. In some cases, the same test measures were evaluated in different studies and did not have consistent findings (see Table 5), while 12 other test measures did not show any significant group differences (see Table 6).

### Results Presented by Test Category

The results of each test are presented below by their corresponding category including questionnaires

**Table 4.** Test measures by included articles.

| Study | Questionnaires | Electrophysiological testing | Speech tests | Auditory processing disorder tests | Non-audiological tests |
|---|---|---|---|---|---|
| Bramhall et al., 2021 | | ABR, EFR | | | |
| Bramhall et al., 2021 | | MEMR | | | |
| Bressler et al., 2017 | SSQ | EFR | | | |
| Gallun et al., 2012 | | ABR | | DD, GIN, MLD-500, SSW | |
| Gallun et al., 2016 | HHIA | | | GIN, MLD-500, SSW | MMSE, PC-PTSD |
| Jedlicka & Zhen, 2023 | HHIA | | | | |
| Koebli et al., 2020 | | | | SCAN 3A | ACT, CASL, CELF-5, SDMT, TMT |
| Kubli et al., 2017 | | ABR, P300 | | MLD-500 | |
| Papesh et al., 2019 | FHQ, HHIA | ASR, P200 | AzBio, CNC | SSW | |
| Papesh et al., 2021 | | | AzBio, BKB-SIN | | |
| Saunders et al., 2015 | | | HINT, LiSN-S | SSW | |
| Saunders et al., 2018 | | | | SSW | |

*Note.* ABR = auditory brainstem response; EFR = envelope following response; MEMR = middle ear muscle reflex; SSQ = Speech, Spatial, and Qualities of Hearing Scale; DD = dichotic digits; GIN = gaps in noise test; MLD-500 = Masking Level Difference–500 Hz; SSW = Staggered Spondaic Words; HHIA-S = Hearing Handicap Inventory for Adults (Screening Version); MMSE = Mini-Mental Status Examination; PC-PTSD = Primary Care Posttraumatic Stress Disorder Screen; ACT = Auditory Consonant Trigrams Test; CASL = Comprehensive Assessment of Spoken Language; CELF-5 = Clinical Evaluation of Communication Skills–Fifth Edition: Metalinguistics; SDMT = Symbol Digits Modality Test; TMT = Trail Making Test; FHQ = mean Functional Hearing Questionnaire; ASR = Acoustic Startle Reflex; CNC = consonant–nucleus–consonant words; SSW = Staggered Spondaic Word; AzBio = AzBio Sentences; BKB-SIN = Bamford–Kowal–Bench speech-in-noise test; HINT = Hearing in Noise Test; LiSN-S = Listening in Spatialized Noise Test.

(see Figure 3), electrophysiological tests (see Figure 4), speech tests (see Figure 5), auditory processing disorder tests (see Figure 6), and non-audiological tests (see Figure 7). The Hedges' *g* values are reported for all tests that found a significant difference between the SPHH-NA group and control groups. These results also are shown in the figures corresponding to each section showing the level of effect size of each measure evaluated in their respective category.

## *Questionnaires*

### Hearing Handicap Inventory for Adults—Screening Version

The Hearing Handicap Inventory for Adults (HHIA) is a 25-item questionnaire that identifies self-perceived hearing loss. A screening version of the test, the HHIA–Screening Version (HHIA-S), is an abbreviated 10 questions of the original HHIA. The HHIA-S had a large effect size in three different

**Table 5.** Test measures with significant differences between groups.

| Tests showing differences between SPHH-NA and control groups | Category |
|---|---|
| AzBio (at 0 dB SNR) | Speech test |
| Auditory brainstem response (ABR) | Electrophysiological test |
| Acoustic startle reflex (ASR) | Electrophysiological test |
| Distortion product otoacoustic emissions (DPOAE) | Electrophysiological test |
| Envelope following response (EFR) | Electrophysiological test |
| Hearing Handicap Inventory for Adults–Screening Version (HHIA-S) | Questionnaire |
| Hearing in Noise Test (HINT) | Speech test |
| Listening in Spatialized Noise Test (LiSN-S) | Speech test |
| Mean Functional Hearing Questionnaire (FHQ) | Questionnaire |
| P200 | Electrophysiological test |
| P300 | Electrophysiological test |
| Primary Care Posttraumatic Stress Disorder Screen (PC-PTSD) | Non-audiological test |
| Speech, Spatial, and Qualities of Hearing Scale (SSQ) | Questionnaire |
| Staggered Spondaic Words (SSWs) | Speech test |
| Trail Making Test (TMT) | Non-audiological test |

*Note.* SPHH-NA = self-perceived hearing handicap with normal audiometric threshold configurations.

**Table 6.** Test measures without significant differences between groups.

| Tests showing no difference between SPHH-NA and control groups | Category |
|---|---|
| Auditory Consonant Trigrams Test (ACT) | Non-audiological test |
| Bamford–Kowal–Bench speech-in-noise test (BKB-SIN) | Speech test |
| Clinical Evaluation of Communication Skills–Fifth Edition (CELF-5): Metalinguistics (Word Inference section only) | Non-audiological test |
| Comprehensive Assessment of Spoken Language (CASL) | Non-audiological test |
| Consonant–nucleus–consonant (CNC) words | Speech test |
| Dichotic digits test (DD) | Auditory processing test |
| Gaps in noise (GIN) | Auditory processing test |
| Masking Level Difference–500 Hz (MLD-500) | Auditory processing test |
| Middle Ear Muscle Reflex (MEMR) | Electrophysiological test |
| Mini-Mental Status Examination (MMSE) | Non-audiological test |
| SCAN 3A | Auditory processing test |
| Symbol Digits Modality Test (SDMT) | Non-audiological test |

*Note.* SPHH-NA = self-perceived hearing handicap with normal audiometric threshold configurations.

studies. The effect sizes from this measure were the largest found in this review. The reported effect sizes from the three studies were 3.44 (±0.19; Jedlicka & Zhen, 2023), 1.04 (±0.32; Papesh et al., 2019), and 1.52 (±0.40; Gallun et al., 2016).

## Mean Functional Hearing Questionnaire

The Functional Hearing Questionnaire (FHQ) is a hearing questionnaire developed for clinical use at the James A. Haley Veteran's Hospital, which measures the

**Figure 3.** Hedges' measure of effect size values for questionnaires. FHQ = Functional Hearing Questionnaire; HHIA = Hearing Handicap Inventory for Adults; SSQ = Speech, Spatial, and Qualities of Hearing Scale.

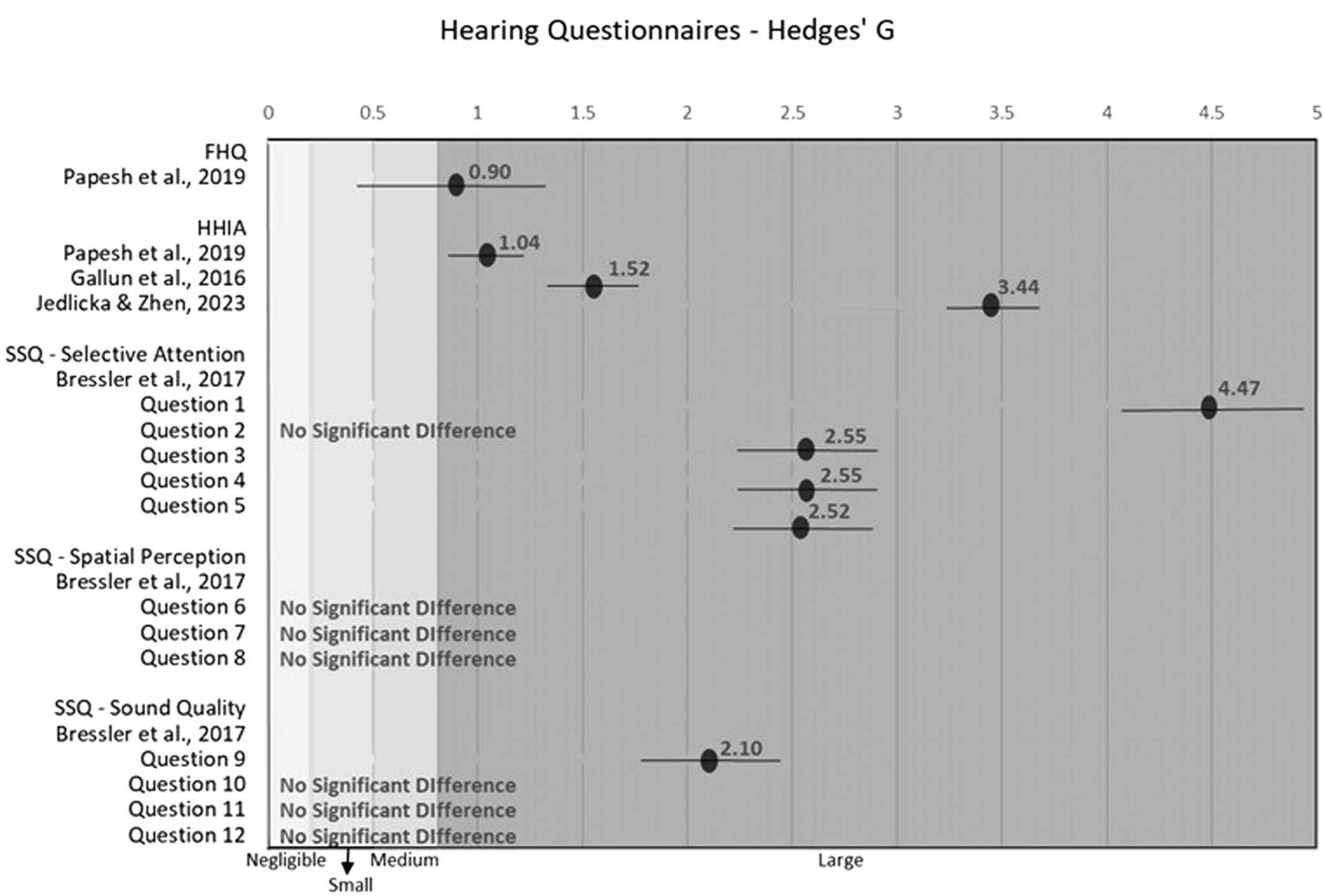
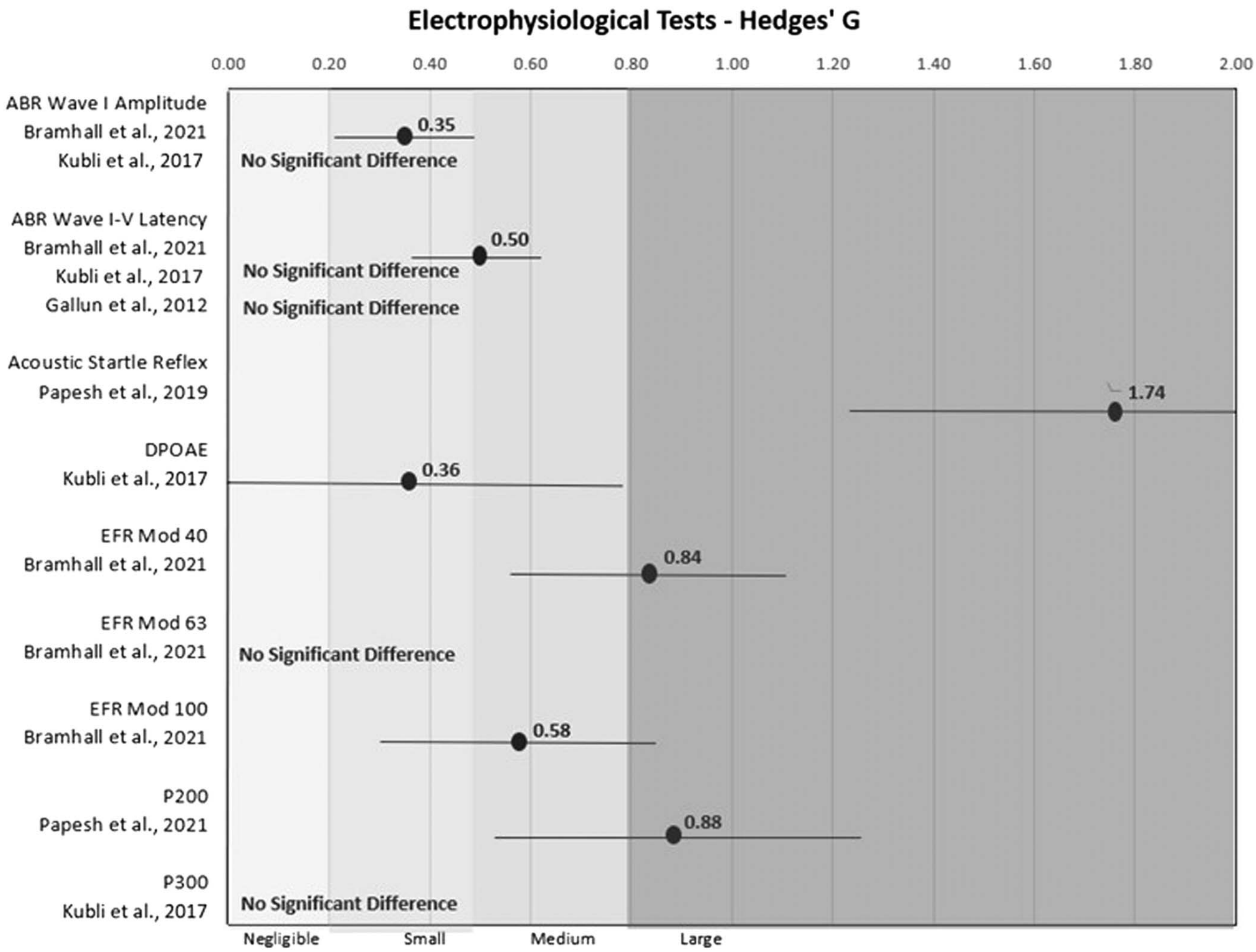


**Figure 4.** Hedges' measure of effect size values for electrophysiological tests. ABR = auditory brainstem response; DPOAE = distortion product otoacoustic emission; EFR = envelope following response.




degree and areas of difficulties in hearing of veterans with mild TBI reporting hearing difficulty despite having normal or near-normal audiometric configurations (Saunders et al., 2015). The results of this questionnaire indicated a significant difference between groups with a large effect size of 0.90 (±0.39; Papesh et al., 2019).

### Speech, Spatial, and Qualities of Hearing Scale

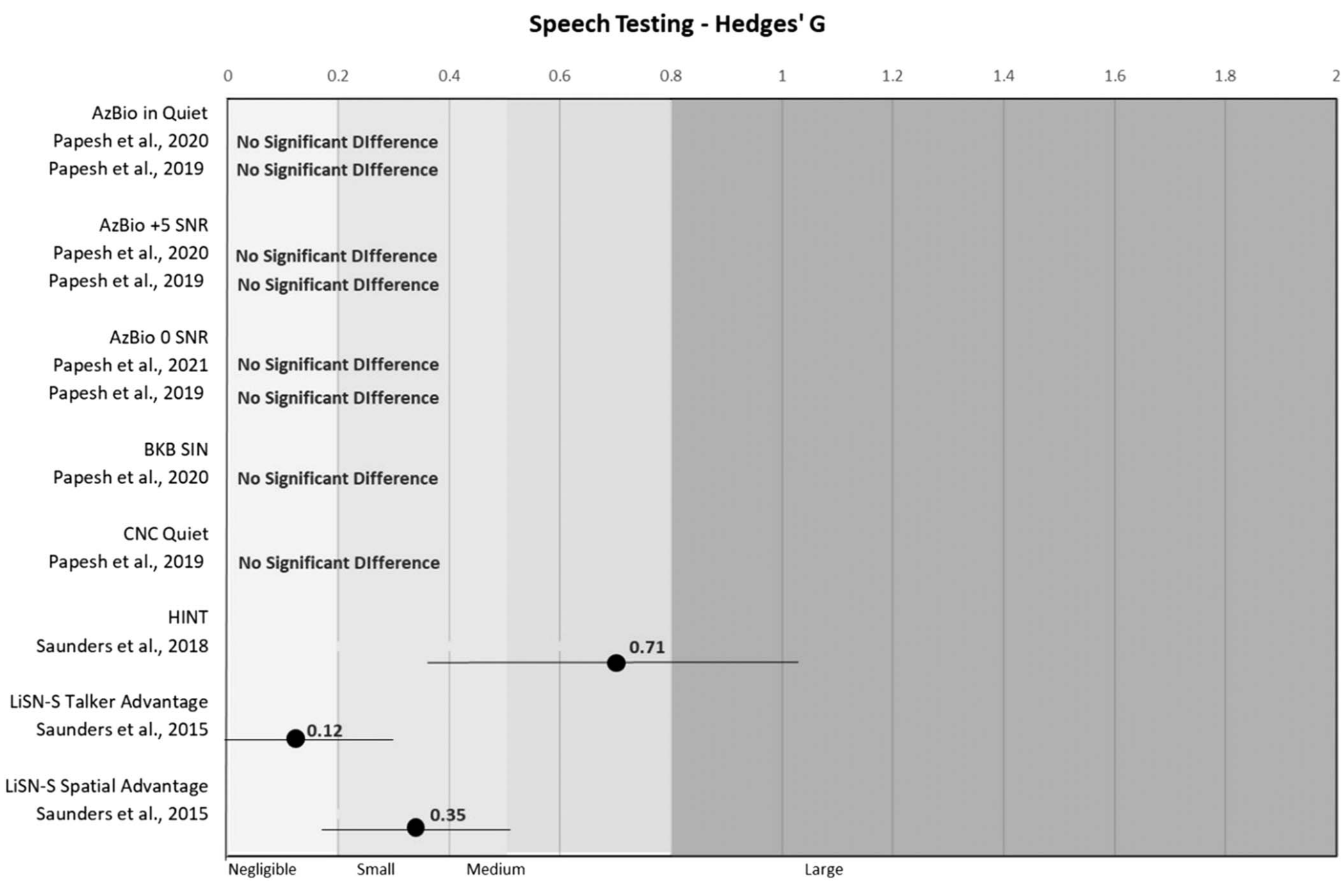
The Speech, Spatial, and Qualities of Hearing Scale (SSQ) was first developed to measure an individuals' perceived hearing ability across several domains (Gatehouse & Noble, 2004). The SSQ asks individuals to self-report how well that person hears in complex listening situations. Eventually, this original version was modified into the more commonly used abbreviated version of the SSQ named SSQ-12 (Noble et al., 2013). The SSQ-12 consists of 12 items across eight pragmatic listening subscales compared to the original 49 item questionnaire. A significant difference, with large effect sizes, between experimental and control groups was found on the following SSQ items (Bressler et al., 2017):

*Item 1 (hearing-in-noise subscale)*. You are talking with one other person and there is a TV on in the same room. Without turning the TV down, can you follow what the person you are talking to say? Effect size: 4.47 (±0.41).

*Item 3 (hearing-in-noise subscale)*. You are in conversation with one person in a room where there are many other people talking. Can you follow what the person you are talking to is saying? Effect size: 2.55 (±0.33).

*Item 4 (hearing in noise subscale)*. You are in a group of about five people in a busy restaurant. You can see everyone else in the group. Can you follow the conversation? Effect size: 2.55 (±0.33).

Figure 5. Hedges' measure of effect size values for speech testing. SNR = signal-to-noise ratio; BKB-SIN = Bamford–Kowal–Bench speech-in-noise test; CNC = consonant–nucleus–consonant words; HINT = Hearing in Noise Test; LiSN-S = Listening in Spatialized Noise Test.




*Item 5 (multiple speech streams subscale)*. You are with a group and the conversation switches from one person to another. Can you easily follow the conversation without missing the start of what each new speaker is saying? Effect size: 2.52 (±0.33).

*Item 9 (segregation subscale)*. When you hear more than one sound at a time, do you have the impression that it seems like a single jumbled sound? Effect size: 2.10 (±0.32).

There were no significant differences between groups for the other questions, which included the subscales of speech in quiet, localization, distance and movement, identification of sound, quality and naturalness, and listening effort.

## Electrophysiological Tests

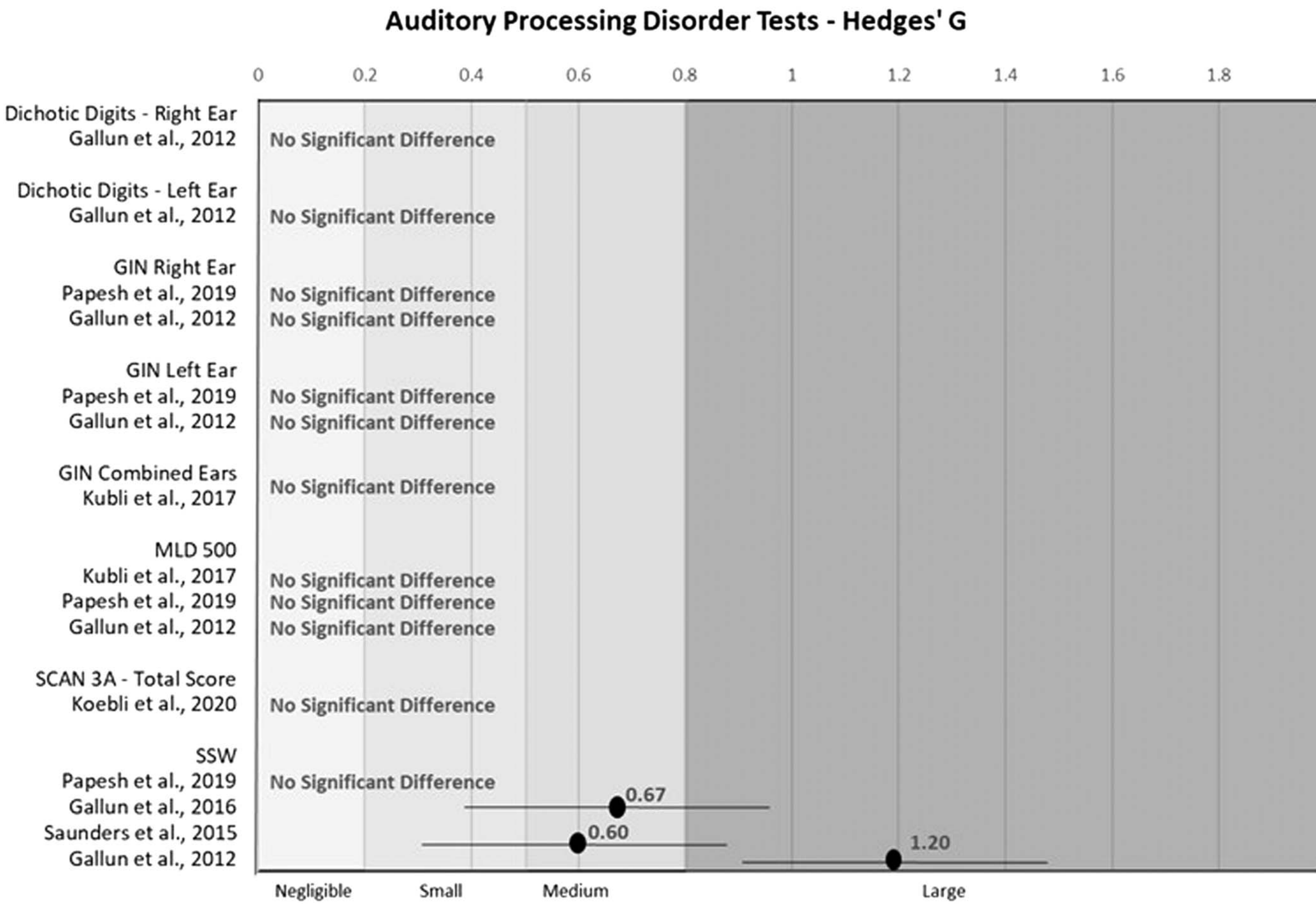
### ABR

The ABR is a measure of the auditory neural pathway and also can be used to measure hearing thresholds. Bramhall et al. (2021) collected ABR data at three different presentation levels (90, 100, and 110 dB nHL). For the purposes of this study, only the data from the 110 dB nHL presentation were included. This selection was made as this presentation level revealed the greatest number of present responses among all participants.

Three groups were evaluated including veterans with high noise exposure, veterans with medium noise exposure, and nonveteran controls. All participants met the inclusion criteria for the purposes of this review. This article did not publish $p$ values for significance; however, the ABR data were obtained by the lead author and two sample $t$ tests assuming unequal variances were completed to determine if significant differences were present between the groups (Bramhall et al., 2021).

Significant differences were found between the veteran high noise and nonveteran control groups for the ABR wave I amplitudes with a small effect size of 0.35 (±0.10). Additionally, there was a significant difference between veteran high noise and nonveteran controls as well as veteran high noise and veteran medium noise for ABR Wave I–V latencies. The difference in Wave I-V latency for

**Figure 6.** Hedges' measure of effect size values for auditory processing disorder measures. GIN = gaps in noise test; MLD-500 = Masking Level Difference–500 Hz; SSW = Staggered Spondaic Words.




veteran high noise and nonveteran controls had a medium effect size of 0.50 (±0.10), whereas the effect size was small, at 0.30 (±0.11) for the Wave I-V latency between veteran high noise and veteran medium noise.

Other ABR measures were evaluated but did not reveal significant differences between the groups (Gallun et al., 2012; Kubli et al., 2017). These measures included Wave V latency, Wave V amplitude, and Wave V-to-1 amplitude ratio.

## Acoustic Startle Reflex

The acoustic startle reflex (ASR) is measured by electromyography and is a measure of the body's response to an unexpected stimulus. The acoustic startle reflex found the largest effect size in the electrophysiological tests category of 1.74 (±0.52; Papesh et al., 2019). The authors did note that this could not be completed with several subjects in both the SPHH-NA and normal hearing control groups due to the nature of the testing (loud signal) and patient reports of PTSD.

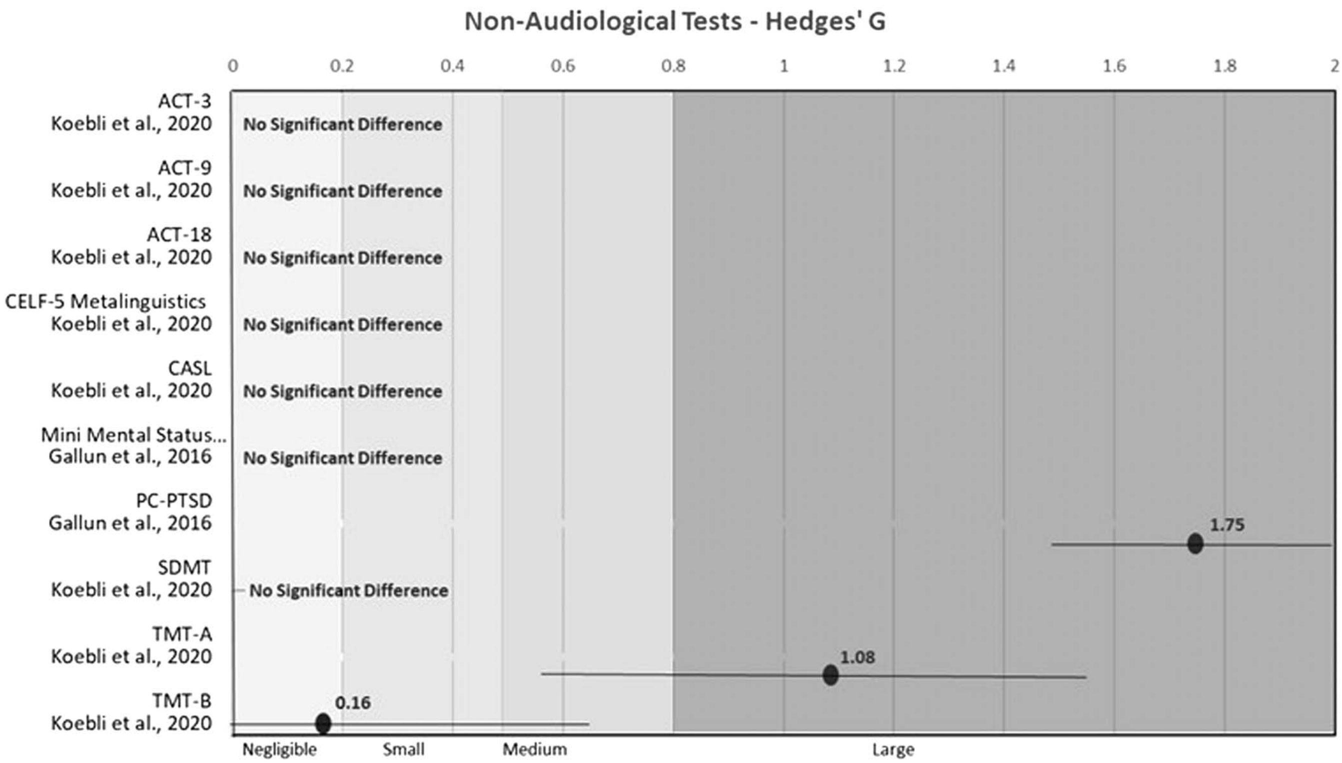
## DPOAE

DPOAE is a measure of cochlear outer hair cell integrity. DPOAE measures were reported in two articles. One article reported a significant difference between groups. The effect size was found to be small at 0.36 (±0.34; Kubli et al., 2017). The other article did not report any significant differences between groups (Bramhall et al., 2021).

## Envelope Following Response

The envelope following response (EFR) is an evoked response following the modulation envelope of a stimulus to measure auditory encoding. Two studies evaluated the EFR and reported conflicting findings. Both studies included measurements of different modulation depths. Bramhall et al. (2021) found varying effect sizes for the differences in groups based on different amplitude modulation depths. At 40% modulation, there was a large effect size of 0.84 (±0.28); at 100% modulation, there was a medium effect size of 0.58 (±0.28); and no group differences were found when measured at 63% modulation depth.

**Figure 7.** Hedges' measure of effect size effect size values for non-audiological tests. CELF-5: Clinical Evaluation of Communication Skills–Fifth Edition: Metalinguistics; CASL = Comprehensive Assessment of Spoken Language; PC-PTSD = Primary Care Posttraumatic Stress Disorder Screen; SDMT = Symbol Digits Modality Test; TMT = Trail Making Test.




Bressler et al. (2017) did not find any differences between the SPHH-NA and normal hearing control groups.

### Middle Ear Muscle Reflex

The middle ear muscle reflex (MEMR) is a contraction of the middle ear muscles in response to a loud sound. This response is triggered both ipsilaterally and contralaterally in most normal hearing individuals. Bramhall et al. (2021) reported no significant measured difference in the MEMR between groups.

### P200 and P300

The P200 and P300 measures are event-related potentials that are measured using electroencephalography (EEG). The P200 is measured by recording the response of an EEG target stimulus approximately 200 ms following the presentation. The P300 is a long latency event-related potential measured using EEG. The P300 is often used as a cognitive test; however, in the field of audiology, this measure is used for the purposes of testing attention and auditory discrimination. The findings from the P200 latencies measures revealed large effect size of 0.88 (±0.36), but P200 amplitudes were not significantly different (Papesh et al., 2021). Discrepancies were found in the P300 as Papesh et al. (2021) found significant differences in P300 latencies but not in P300 amplitudes while there were no significant differences in latency or amplitude for the P300 (Kubli et al., 2017) measures between groups. Papesh et al. (2021) also evaluated P300 responses between groups but reported that, "Due to the variability among blast-exposed participants, grand averaged waveforms may not be representative of individuals in the group."

## *Speech Testing*

### AzBio at 0 dB SNR

AzBio is a 15-sentence speech understanding test that can be measured in quiet or with competing background noise. The author of these studies completed the testing in quiet and with varying levels of signal-to-noise ratios. There were no significant differences between groups in AzBio performance in quiet or in noise (Papesh et al., 2019, 2021).

### Bamford–Kowal–Bench Speech in Noise

The BKB-SIN (Bamford–Kowal–Bench speech in noise) is a speech-in-noise test featuring 4-person babble as the background stimulus. This test is used in the adult and adolescent population. No significant differences were found between groups using this measure.

### Consonant–Nucleus–Consonant Words in Quiet

The CNC (consonant–nucleus–consonant) word list is a phonetically balanced speech test consisting of 10 lists of 50 words. No significant differences were found between groups using this measure.

### Hearing in Noise Test

The Hearing in Noise Test (HINT) is an adaptive HINT used to measure an individual's ability to hear in noisy and quiet settings. Saunders et al. (2015) reported a significant difference between the groups with the SPHH-NA group performing worse on the HINT than the normal hearing control group without SPHH. The difference between the groups was found to have a large effect size of 0.71 (±0.36; Saunders et al., 2015).

### LiSN-S

The LiSN-S is a speech-in-noise test that includes testing an individual's performance when listening to the same speaker or different speakers (talker advantage) as well as performance understanding in noise when the noise source azimuths are varied (spatial advantage). There was a significant difference between the SPHH-NA and normal hearing control groups without SPHH. Saunders et al. (2015) measured both conditions. The effect size for the talker advantage was negligible at 0.12 (±0.17), and the effect size for the spatial advantage was small at 0.35 (±0.18). Saunders et al. (2015) used normative data from a separate study to compare the performance of their participants to determine if differences were found (Brown et al., 2010). The adult normative data from Brown et al. (2010) were used as a proxy to calculate Hedges' *g* for this measure, since it was also used by Saunders et al. (2015) for comparison.

## *Auditory Processing Disorder Measures*

Numerous auditory processing disorder measures were used in the assessment of the SPHH-NA population across several studies. Dichotic digits, gaps in noise, masking level difference for 500 Hz (MLD 500), and the SCAN 3A did not find significant differences between groups.

### Staggered Spondaic Words

The Staggered Spondaic Words (SSW) is a dichotic listening test used in the evaluation of APD. The SSW test was the only auditory processing disorder test that found significant differences between groups. Four studies evaluated the SSW with one study showing no significant difference and three other studies showing a significant difference between groups. The calculated effect sizes of the studies finding group differences were different with Gallun et al. (2012), having a large effect size of 1.20 (±0.27), while Gallun et al. (2016) found a medium effect size of 0.67 (±0.27) and Saunders et al. (2015, 2018) reported a medium effect size of 0.60 (±0.27).

## *Nonaudiological Tests*

Several nonaudiological tests were administered and did not reveal differences between the SPHH-NA and normal hearing control without SPHH. These tests include the Auditory Consonant Trigrams, Clinical Evaluation of Communication Skills–Fifth Edition (CELF-5): Metalinguistics, Comprehensive Assessment of Spoken Language, Mini-Mental Status Examination (MMSE), and Symbol Digits Modality Test (SDMT).

### Primary Care PTSD Screen

The Primary Care PTSD Screen (PC-PTSD) is a four-item questionnaire designed to screen service members for PTSD (Bliese et al., 2008). There was a significant difference between the groups with an extremely large effect size of 1.75 (±0.27).

### Trail Making Tasks (Parts A and B)

The Trail Making Task (Reitan, 1958) is a test designed to measure central executive functioning. The tasks require participants to correctly connect dots in a sequential order. The test is scored based on accuracy and time to complete the test. Part A consists of connecting 25 numbers, while Part B requires the participant to connect the dots in a number–letter–number–letter format. Part B is more challenging than Part A due to being a more cognitively challenging test, having more distracting stimuli, a larger test area, and increased motor speed demands (Gaudino et al., 1995). SPHH-NA participants in the Koebli et al. (2020) study had significantly worse performance on both parts compared to normal hearing controls without SPHH. The effect size for Part A was large (1.08 ± 0.52), while the effect size for part B was negligible (0.16 ± 0.50). This result is unexpected as Part A is a less-challenging measure than Part B.

# Discussion

The aim of this study was to determine which assessment measures identify differences in performance between veterans with SPHH-NA and audiometrically normal control groups with no reported SPHH. Self-report questionnaires provided the most consistent metric that differentiated people with SPHH-NA from controls. Other tests including the HINT, PTSD screener, P200, P300, acoustic startle reflex, and Trail Making Test found large effect sizes differentiating the groups, albeit only in one study each. These findings, although limited, may guide future research by highlighting specific functional domains to investigate in those with SPHH-NA. Other measures, such as the ABR and SSW, found conflicting results with some studies showing differences between groups and others showing no differences.

Many tests, which are recommended in the assessment of this population, showed no differences between groups, negligible effect sizes, or inconsistent findings across studies. The findings of this rapid scoping review demonstrate that we have a limited number of tests that consistently identify differences between people with SPHH-NA and controls. Given the limited number of repeatable findings, which show a significant difference between groups and large effect sizes, we cannot recommend a comprehensive test battery to confirm SPHH-NA and therefore cannot provide evidence-based treatment.

One consideration as to why the hearing questionnaires were the only measure to consistently show large effect sizes is due to the possibility of pseudohypacusis. It is unlikely that pseudohypacusis is present in this population as this phenomenon reporting significant hearing difficulties despite audiological tests showing performance within normal limits has been documented in the research since the 1980s. This phenomenon was first classified as King-Kopetzky syndrome and has been labeled with several names since it was first identified. Given that this report of hearing difficulties despite having no measured hearing loss is present in both the veteran and nonveteran population, it is unlikely pseudohypacusis would serve as a main contributor for large effect sizes in the self-report questionnaires category.

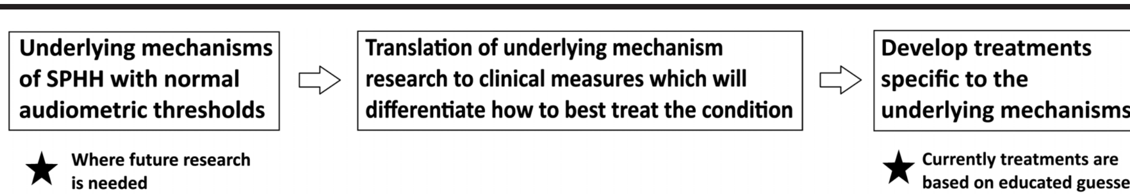
Despite the lack of consistent measures to test this population, individuals who perceive hearing difficulties are likely to seek help from audiologists who are the experts in diagnosing and treating hearing impairments. These individuals often report that their main hearing difficulties occur when trying to understand speech in complex listening environments. It is possible the reason these individuals with SPHH-NA perceive difficulty in complex listening environments is because understanding speech in these environments requires resources from more than the auditory system alone. This could be a primary explanation for why typical audiometric tests have not provided a robust way to identify these individuals.

Many of our measures are completed in environments without any visual or auditory distractors therefore not mimicking or predicting how an individual will function in the real world. In addition, we currently do not have a mechanism for controlling for or reporting effort that is used to complete auditory testing, which may be another element that might differentiate these populations. Typical audiological test measures do not task higher level processing such as cognition, attention, and effort, which may play a role in the issues reported by individuals with SPHH-NA. To date, we have very limited data related to these functions in this population. There is preliminary evidence from this rapid scoping review to support the use of tests, which evaluates higher level processing abilities in this population.

An abundance of evidence exists suggesting aging, fatigue, environmental distractors, attention, specific comorbidities such as PTSD, and other possible factors all play a role in an individual's ability to understand speech in noise (Cohen & Gordon-Salant, 2017; Jedlicka & Zhen, 2023; Landström, 1990; Rönnberg et al., 2010; Schneider et al., 2000; Zink et al., 2024), which is the most common complaint from individuals with SPHH-NA. We must consider these non-audiological factors in this target population. Despite knowing about this condition for many decades, we are still without adequate test and treatment options. The future of research in this area should take a step back from focusing solely on assessment and experimental treatments of this condition and explore the underlying mechanisms to determine why these individuals are experiencing SPHH-NA (see Figure 8). Expanding our knowledge to identify the source of the impairment will guide our assessment and treatment recommendations rather than simply using common and familiar assessment and treatment tools.

Taking a global view of all the factors that influence our ability to hear and understand speech in adverse listening environments may provide new perspectives that lead to better outcomes for patients. There may be support for transdisciplinary care and research should we continue to see evidence that non-audiological measures such as the PTSD screener and Trail Making Task are able to confirm SPHH-NA. Ultimately, these are new and expanding perspectives that should be considered. Audiologists may need to leave the comfort zone of familiar tests and treatments to meet the needs of the patient population with SPHH and normal audiometric thresholds (SPHH-NA).

**Figure 8.** Recommended flowchart for future research of self-perceived hearing handicap with normal audiometric threshold configurations (SPHH-NA).



## Study Limitations

Exclusion of articles without full online access may have limited the scope and completeness of the review and introduced bias, especially if only open-access articles were reviewed. Hedges' *g* was used to calculate effect size as this calculation addresses nonnegligible biases for small sample sizes. Six of the 11 included studies had sample sizes that were deemed to be "small" (fewer than 30 subjects per group). Small sample sizes may lead to increased variability and reduced statistical power.

## Informed Consent

This study was exempted from institutional review board approval due to being a review of published articles.

## Data Availability Statement

Data from this project are available on request from the corresponding author of this study.

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