

Assessing of hearing loss impacts on speech difficulties using speech audiometry

Hael Mahmoud Younes

SAERA. School of Advanced Education Research and Accreditation

ABSTRACT

Background and Objectives: the basic audiological exam includes speech audiometry as a necessary component. The study aimed to assess the effects of hearing loss on speech difficulty in Kurdish populations compared to a healthy control group. In addition, the study aimed to establish a Kurdish Speech Audiometry.

Material and Methods: the case-control study analyzed 100 patients, divided into two groups: 50 with hearing loss and 50 with normal hearing assessed by speech audiometry. The initial clinical interviews with the cases were conducted at Zakho General Hospital in Zakho city in the period from October 1st, 2023, to August 1st, 2024. Examination of the ear canal are performed as the first steps in a basic audiological evaluation, Pure Tone Audiometry and Speech Audiometry. All of the research's variables were covered by a questionnaire that was developed for the study.

Results: sound recognition results were compared between the patients for the right, left, and bilateral ears. Control patients had significantly higher results in speech recognition than patients with hearing loss. Sound recognition threshold in the right ear, with 3 (25%) at 60dB, left ear 10 (83.33%) and bilateral ears 6 (15.79%) at 40dB in the patients. and 0 (0%) in the healthy controls.

Conclusion: the patients with hearing loss have significantly higher rates of speech difficulty compared to the healthy controls. The lists of words can be used as a guide for identification of hearing loss to the Kurdish populations. Observed across the two monosyllabic and polysyllabic word lists. And the lack of differences between Speech Reception Thresholds (SRTs) and Pure Tone Audiometry (PTAs). Identifying the underlying causes and potential interventions for individuals experiencing hearing loss.

Keywords: *pure Tone Audiometry, Speech Audiometry Test, Hearing Loss, Sound Detection Threshold and Sound Recognition Threshold.*

INTRODUCTION

Speech audiometry is an essential part of audiological diagnostics and clinical measurements (Nuesse et al., 2019). Typically consists of determining the speech recognition threshold (SRT), the word recognition score (WRS) is established in quiet and, preferably, also in noise (Punch & Rakerd, 2019).

Speech is a particularly human tool for the expression of emotion, exchange of thoughts, and conveyance of information (Ma et al., 2013). Humans require speech perception and comprehension in order to communicate normally. Many individuals with hearing loss say that they have difficulty understanding speech in everyday circumstances (Parmar et al., 2022).

Speech audiometry is typically used to calculate the speech recognition threshold (SRT). Conducting listening trials, which frequently have the goal of determining the (SRT), are the gold standard for evaluating these algorithms. i.e., the signal-to-noise ratio (SNR) at which a particular proportion (often 50%) of words are identified. Speech audiometry tests were not introduced until the 1950s, and standardized test materials are still in short supply (Ma et al., 2013; Roßbach et al., 2022).

The word recognition score (WRS) is the most crucial and widely utilized component of speech audiometry in current diagnostic audiology, word recognition testing is one of the most important procedures. When the words are delivered in a standardized context and the presentation level is at a suprathreshold level, it measures one's capacity to reliably recognize a list of spoken words (i.e., Pure tones are audible above the lowest feeling level) that is loud enough to

provide the best results in terms of recognition (Nissen et al., 2005). Many additional languages, including Japanese (Sakamoto et al., 2006), make use of the WRS, such as Turkish (Kemaloğlu et al., 2017) and Arabic. In the Egyptian press, word lists in Arabic have been reported (Soliman, 1985), as well as the cases of Moroccan (Messouak, 1956), Iraqi (Alusi et al., 1974), Saudi (Ashoor & Prochazka, 1982), Jordanian (Garadat et al., 2017), and other studies. Previous Jordanian have found no significant variations in WRS in normal hearing Jordanians depending on ear or gender characteristics at the pleasant feeling level (Al Matar, 2021).

Regardless, the most used technique for measuring auditory perception is PTA, due to the fact that it gauges a listener's openness to sound rather than their functioning hearing abilities, speech perception may not always be predicted with precision by pure tone audiometry (De Sousa et al., 2020). The fundamental information on hearing acuity is provided by a pure tone audiogram, and the Pure-Tone Audiometry (PTA) with speech intelligibility is a representation of a person's overall hearing condition. In addition to serving as the foundation for speech discrimination testing, speech recognition threshold (SRT) also conveys the accuracy of a pure tone audiogram. When a patient is most likely to have a functional hearing loss (FHL), consistency between the PTA and SRT is crucial (Kim et al., 2016).

Due to the additional evaluation of more complex language processes and the impact of environmental restrictions on the processing of auditory information, speech tests are often considered to be more clinically acceptable than pure-tone

audiometry for detecting patients with subpar auditory analytical skills (Wang et al., 2007).

During a typical speech audiometric exam, the subject is repeatedly given with short words that are delivered acoustically. CVC words with only one syllable often make up the stimulus. The advantage of using this kind of stimulus is that there is less language context to draw missing information from. The test's findings are widely regarded as being particularly instructive in terms of how speech information is processed from the inside out, or at the inner ear level (Coene et al., 2015).

Individual hearing qualities vary, and hearing is limited by age. Because hearing loss cases due to noise are on the rise, in addition to ear injury caused by electronic equipment and media development, noise induced deafness is steadily increasing among young college students (Jeung et al., 2015).

Importance of the study

There are many different cases in the Kurdistan region that need diagnosis by Speech Audiometry Test. Also, the present study is very necessary for comparing types of hearing loss and speech difficulties. Additionally, it aims to contribute to the field by developing linguistically appropriate materials specifically tailored for evaluating speech perception in native speakers of the Kurdistan Region

Aims of the study

Evaluate the effects of hearing loss on speech difficulty in Kurdish populations. In addition, the study aimed to establish a Kurdish Speech Audiometry.

Objectives of the study

1. To determine the syllables for speech audiometry testing, named KSA (Kurdish Speech Audiometry).
2. To evaluate the effectiveness of speech audiometry upon hearing loss and speech difficulty in Zakho city.

REVIEW OF LITERATURE

1. Historical Background of Speech Audiometry Test

Humans use speech as an auditory stimulus to communicate, making voice recognition crucial. After World War II, speech audiometry gained prominence due to returning soldiers with hearing loss, building on Bell Labs research from the 1920s and 1930s on communication systems. This study has recently tested various speech assessments, including phonemically balanced monosyllables and synthetic sentence identification, to gather more diagnostic data. Since the early 20th century, pure-tone audiometry has assessed hearing sensitivity, while speech perception measures have been used in the US since the late 1940s to evaluate factors like speech pattern recognition and reception thresholds. Over the past 50 years, numerous speech perception tests have been developed. Oscar Wolf views speech as the best method for evaluating hearing due to its sensitivity to sound nuances, though Gruber (1891) emphasized its importance, and Hartmann criticized its complexity. Despite past research with tuning forks showing similar hearing loss in both ears, speech perception tests should be conducted separately for each ear, as speech perception may vary compared to simple sounds.

Repeatedly testing words helps manage perception (Wilson & McArdle, 2005). Research on speech-recognition ability has explored the link between words and sentences for over 50 years. Egan (1944) found that sentence performance was generally better than single words, with variations in signal-to-noise ratio (SNR) affecting performance. Egan reported that isolated words required a 4 dB SNR for 50% accuracy, while phrases needed only 2 dB SNR (Miller et al., 1951). Speech audiometry, as defined by Kumar & Mohanty (2012), involves evaluating auditory systems using standardized speech stimuli. Carhart's 1951 study identified two types of hearing loss: "loss of acuity," marked by a shift in articulation function, and "lack of clarity," where hearing acuity can't be significantly improved regardless of signal strength (Carhart, 1951).

2. Hearing Loss

Hearing loss is common and can severely impact various aspects of life if untreated. It can delay language development in children, increase the risk of cognitive decline, and affect emotional well-being, leading to issues like loneliness and anxiety (Haile et al., 2021). Hearing loss can affect anyone, from children to the elderly, impacting speech development in kids and social and employment opportunities for adults. It can result from problems in various parts of the auditory system, including the cochlea and auditory pathways. Effective rehabilitation is available for all types of hearing loss, and early detection by primary care physicians is crucial (Lasak et al., 2014). Speech audiometry is a fundamental audiological test that requires reliable practices and materials to be effective (Van Zyl et al., 2018). It involves presenting syllables,

phrases, or sentences at specific volumes and measuring the subject's responses to determine their speech recognition threshold (SRT). This threshold indicates the lowest signal-to-noise ratio at which speech is understood 50% of the time. The speech discrimination score, or word recognition score (WRS), assesses hearing capacity and helps validate other test results (Øygarden, 2009). Accurate auditory input is crucial during early language development to form a phonological framework (Iliadou et al., 2015). Speech stimuli used in audiometry, such as consonants, words, and sentences, are vital for understanding daily communication (Kumar & Mohanty, 2012). To determine the type and severity of hearing loss in those over four years old and to design effective treatments, pure tone audiometry is typically the first test conducted. It involves various audiometers, from simple screening tools to advanced diagnostic devices, and provides both quantitative and qualitative hearing data. However, it does not fully represent a patient's ability to comprehend speech (Boboshko et al., 2017).

3. The Pathway of Hearing Sound

Understanding how information is transmitted to and interpreted by the brain is crucial, as data only becomes meaningful when perceived. The auditory system consists of peripheral and central components. The peripheral system, which includes the auditory nerve and the outer, middle, and inner ears, converts sound into electrical impulses sent to the brain with details on timing, frequency, and intensity (Musiek & Baran, 2018).

The outer ear has the external auditory canal and pinna, which help capture sound. The middle ear features three small bones

(ossicles)—malleus, incus, and stapes—and connects to the nasopharynx via the eustachian tube to balance pressure and allow drainage (Møller, 2012).

The central auditory system includes the brainstem, midbrain, and cortical nuclei, forming a complex network (Kramer & Brown, 2021). Neuronal impulses from the cochlear nucleus are processed by the auditory cortex. Sound travels through the auditory system: entering the outer ear, passing through the middle ear, reaching the inner ear, and then traveling via neuronal pathways (Musiek & Baran, 2018).

The auditory nerve receives sound as acoustic energy, which the middle and inner ears convert into mechanical energy. In the cochlea, hair cells transduce this into neural signals (Møller, 2012). The middle ear enhances sound energy transfer to the cochlea and reduces sound reflection through acoustic impedance matching. The cochlea, a spiral-shaped structure, contains three fluid-filled channels: scala vestibuli, scala media, and scala tympani. The basilar membrane within the cochlea sorts sounds by frequency, with low frequencies at the apex and high frequencies at the base (Musiek & Baran, 2018).

The organ of Corti, supported by the basilar membrane, contains sensory cells. Outer hair cells (OHCs) amplify vibrations and refine frequency tuning, while inner hair cells (IHCs) convert vibrations into neural impulses. These impulses travel through the eighth cranial nerve to the brainstem, where the auditory cortex processes them for sound analysis, localization, inhibition, and pattern recognition (Musiek & Baran, 2018).

4. Epidemiological

Hearing loss becomes more common as people age, often detected through family concerns or social withdrawal. In the U.S., about 28 million adults have some level of hearing impairment, according to a study of 2,837 adults that assessed hearing loss by age group (Lasak et al., 2014).

Hearing loss is a global issue, affecting millions and ranking as the fourth most common impairment (WHO Global Health Estimates, 2015; Cunningham & Tucci, 2017). A New Zealand study projected hearing loss trends over fifty years, factoring in the aging population (Exeter et al., 2015).

Audiometry traditionally measures hearing by assessing word recognition accuracy, but listening effort research shows that cognitive resources also impact performance, even when recognition is nearly perfect (Meister, 2018).

Gelfand (2007) outlines the purposes of Clinical Speech Recognition scores: 1) Assess hearing loss severity and impact on verbal understanding. 2) Identify the anatomical source of hearing issues. 3) Determine the need for hearing aids or other rehabilitation technologies. 4) Compare different hearing aids and amplification strategies. 5) Demonstrate the benefits of hearing aids. 6) Monitor patient progress for diagnosis and treatment (Kumar & Mohanty, 2012).

In Estonia, modern speech perception tests are lacking. Existing Soviet-era tests, which use monosyllables and multisyllabic numbers, are rarely used due to poor quality and limited professionals. Audiology is not a separate academic field in Estonia, with otolaryngologists and nurses handling

audiology tasks. As a result, pure-tone audiometry is the most common method used (Veispak et al., 2015).

Pure-tone audiograms do not fully capture speech communication difficulties caused by hearing loss. Speech stimuli should be included in hearing tests since individuals with hearing loss often struggle with speech (Trimmis et al., 2006).

Word recognition score (WRS) is crucial for assessing hearing in everyday conditions, as pure-tone audiometry (PTA) alone is insufficient. Many audiologists in Arab countries do not use WRS in standard exams, and those who do often use monitored live voice (MLV) testing, which can produce inconsistent results (Najem & Marie, 2021).

Speech-word recognition tests help audiologists gauge hearing loss severity, identify auditory issues, determine the need for rehabilitation, confirm hearing aid benefits, and track patient progress (Coene et al., 2015).

In the Kurdistan Region/Iraq, Kurdish-speaking patients can now be evaluated using standardized digitally recorded materials, including all Kurdish consonant phonemes. The study designed lists to include each consonant phoneme, including less common ones like /ɣ, ɣ̤/, in various word positions (Hamarashid et al., 2021).

Kurdish phonetics typically include 26 to 28 consonants and nine phonemic vowels, with variations based on word position. Non-phonemic vowels are also considered important (see Table 1.). Kurdish vowel sounds can differ from English, such as the vowel sound in "around" compared to "bell" (Hamarashid et al., 2021).

5. Clinical Hearing Evaluation

Pure tones and speech are the two main types of auditory stimuli used in clinical hearing tests, each providing valuable information about auditory system accuracy. Pure-tone audiometry uses simple, non-speech signals to assess hearing, while speech audiometry involves evaluating responses to speech stimuli like syllables, words, and phrases. Pure-tone audiometry helps determine the type and severity of hearing loss and whether further tests or treatments are needed, making it a straightforward procedure (Kumar & Mohanty, 2012).

Speech perception can vary among patients even with identical threshold audiograms. Speech audiometry is used to assess this variability. The process involves recording speech or words with high-quality equipment, then playing it through headphones. Word groupings are chosen for their phonetic consistency and adherence to the language's structure. Each syllable's volume is uniform, and a voltmeter controls this. Fifty words are recorded per session, and the attenuator adjusts the sound level at which the participant can hear the words. The intelligibility curve is plotted using at least three data points. In cases of conductive hearing loss, intelligibility thresholds are typically 40–50 dB higher than normal, with the intelligibility curve remaining parallel to the normal curve. For sensorineural hearing loss, the curve diverges from the typical pattern (Kapul et al., 2017).

Patients with presbycusis often struggle with understanding speech. Evaluating their hearing and comprehension is crucial for selecting effective treatments and analyzing outcomes. Speech audiometry, which assesses physiological, linguistic, and psychological aspects of speech, provides a

more comprehensive evaluation than pure-tone testing, making it especially important for those with presbycusis (Kim & Chung, 2013).

6. Laboratory Findings

Butler (2013) tested the impact of modifying acoustic energy on speech perception in individuals with mild to moderate sensory neural hearing loss (SNHL). Results showed no significant difference in performance between modified and unmodified conditions, except for specific cases with an 8 dB/octave filter.

Nisar et al. (2019) introduced a novel approach for automating pure tone and speech audiometry using cognitive science principles. The model, with less than 4.9 dB error compared to professional tests, offers a cost-effective early detection method and a second opinion for audiologists.

Masalski & Kręcki (2013) assessed hearing threshold measurement errors, finding that calibration and frequency nonlinearity errors significantly affected results. They suggested potential for web-based pure-tone audiometry with reduced measurement errors. Coene et al. (2015) investigated the contribution of auditory versus linguistic factors in speech audiometry tasks. Their study highlighted that consonant replacements in speech recognition are influenced by linguistic knowledge.

Nissen et al. (2011) developed and validated Cantonese speech materials for word recognition, finding consistent psychometric slopes across different talkers and materials. Zhang et al. (2005) revised Mandarin speech test materials, creating sentence lists for

evaluating cochlear implants and hearing aids at various intervention stages.

Morgenstern et al. (2020) highlighted the need for standardized outcome measures in clinical research, noting variability in speech audiometry results due to insufficient documentation. Trimmis et al. (2012) created a nonsensical speech test for Modern Greek, demonstrating list equivalence and its clinical utility. Dias et al. (2015a) developed Konkani speech audiometry tests, finding reliable Speech Identification Scores (SIS) for distinguishing between normal and impaired hearing.

Nuesse et al. (2019b) explored synthetic speech for speech recognition tests, finding it effective and cost-saving compared to natural speech.

Alisaputri (2016) created standardized disyllabic Malay speech tests, showing reliability and consistent speech discrimination across word lists.

Anjos et al. (2014) analyzed the relationship between audiometric findings and Speech Reception Threshold, finding strong correlations with specific frequency averages.

Vanpoucke et al. (2022) developed Dutch speech audiometry tests with consistent recognition thresholds and slopes, offering a valuable addition to current tests.

Ristovska et al. (2022) validated Macedonian speech tests with consistent psychometric functions and audibility across different levels.

Ibelings et al. (2022) assessed if Text-To-Speech systems could replace natural speech in tests, finding synthetic speech slightly less effective but still viable for creating new tests. Chinnaraj et al. (2022) standardized

Tamil disyllabic words for audiometry, showing high speech identification scores and list equivalence. Vaucher et al. (2022) created Portuguese monosyllable lists, confirming their equivalence and reliability for audiometric tests regardless of ear side or educational background.

METHOD

The study design

This is a case-control study, patients who underwent speech audiometry to evaluate the effects of hearing loss on speech difficulties were divided into two groups: study group and control group. The study group comprised patients diagnosed with hearing loss, while the control group consisted of individuals who were healthy, without any reported hearing complaints.

Population and setting

The population of this study was the patients who were assessed with the effects of hearing loss on speech difficulties by speech audiometry at the Audiology center in Zakho city. The patients had different sociodemographic characteristics within Zakho City. The clinical center of Audiology / Speech Audiometry is the only tertiary specialized center for diagnostic and therapeutic services for Audiology / Speech Audiometry patients in Zakho City.

Sample of the study

In this case-control study, the patients who were assessed with the effects of hearing loss on speech difficulties by speech audiometry were included. The patients were then divided into two groups, the first one involved those who were diagnosed with

hearing loss and the second group involved those who were healthy without any complaints or changes in their hearing were determined. Finally, the study included 100 individuals of both genders aged 18-30 years. The participants were divided into two groups: control group (CG), 50 healthy young adults with no hearing complaints or changes, and no systemic diseases; and study group (SG), 50 patients with a diagnosis of hearing loss, matched to the control group for age and gender. The CG was recruited through posters hanging on the walls of the medical college and through invitations made to the persons accompanying the patients, while the SG subjects were recruited at the Educational Hospital & Private Hospital on the Kurdistan Region.

Eligibility Criteria

- The Inclusion and Exclusion Criteria:

The inclusion criteria state that individuals between the ages of 18-30 with normal hearing or any type of hearing loss can participate. However, individuals under 18 or over 30 years old, those with autism, and deaf and mute patients are excluded.

Ethical considerations

The ethical approval of the current study was obtained from the Ethical Committee at the Duhok General Directorate of Health and the Scientific Committee of the Duhok College of Nursing formally approved the study proposal dated 24th – October - 2021 as a reference number: 24102021-10-1 (Appendix A). To make it easier for researchers to do their investigation, a formal request for consent was prepared for Zakho General Hospital. Following the explanation of the study's goal for the students and patients, an oral verbal agreement form was

collected from those who took part; they were given the option to cease or resume their participation at any time. They received a guarantee that all information would be kept confidential. Additionally, participation in this study was entirely optional, and participants were free to withdraw at any moment.

Method of data collection

After getting permission from the Duhok General Directorate of Health and the selected hospital administrations in Zakho City. The researcher collected the data through direct conversations with patients by using a predesigned questionnaire. The information was taken from the patient's face-to-face interview technique. Additionally, the filling of the questionnaire for each patient took around 30–45 minutes. The patients have been informed that all data would be confidential and would only be used for research purposes.

Initial clinical interviews with all subjects were conducted at Zakho General Hospital. Examination of the ear canal are performed as the first steps in a basic audiological evaluation, Speech audiometry, pure tone audiometry (250-8000 Hz), and (speech recognition index (SRI) and speech reception threshold (SRT), likewise acoustic immittance techniques. The individuals wore headphones while undergoing speech audiometry. A clinician-diagnosed middle ear pathology was ruled out with immittance audiometry. All operations were performed with headphones, a free field audiometry amplification device, and an Inter Acoustics two-channel digital audiometer model, which were completed in an audiometric booth. Following the initial audiological

examination, we used Kurdish Speech Audiometry (KSA) (Appendix E & F).

The data collection process was handled by an audiologist with normal hearing. In the monitor room, a loudspeaker that was crystal clear allowed the audiologist to hear the participant's answer. If a participant properly repeated a word, the audiologist would put a checkmark next to it. The audiologist recorded the participant's incorrect words on the data collection form. The audiologist would put an X on the information gathering form if the patient was unable to say it again and made no response. Each participant's pure tone audiometry (PTA) rounded to the nearest 5 dB HL, was computed at 0.5, 1, 2, 4, and 8 kHz. Each word list's PI functions throughout all topic areas was created using the WRSs recorded from -10 to 55 dB SL (PTA) in 5 dB increments.

Time of the Study

The data collection and follow-up for this study took place over a span of six months, from November 20th, 2021, to April 10th, 2022. The overall study period extended from October 1st, 2023, to August 1st, 2024.

Tools of Data Collection

A questionnaire created specifically for the study covers all of the research. The questionnaire for this study was created according to the objectives of the study and was organized and validated, developed using textbooks (Flood, 2016) relevant experts, and other surveys (Cox & Alexander, 1995). (Appendix C)

Speech test:

Based on the plot of Swedish speech banana as shown in Figure 1 (see Figure 1.) the value

at the local maximum of the power spectral density, as noticed, corresponds to each phoneme frequency (Appendix D). The difference between the intensity at the local maxima of power spectral density is what defines each phoneme's intensity specifically (Klangpornkun et al., 2013).

In this study the new words recognition lists created in Kurdish has a total of 2000 potential possibilities when all available combinations are used. We preliminarily constructed a KST (Kurdish Speech Test) from 28 initial consonants, 22 vowels, and 3 tones. The remaining 196 words were created after absurd and improper terms were eliminated. A total of 96 words for the polysyllabic list (Appendix E) and 100 words for the monosyllabic list (Appendix F) were included in each of the two phonemically balanced lists. Due to their vocalic characteristics and classification as semivowels, the two glide consonants (i.e., /ɣ /) were left out of the list of consonants.

In order to diagnose and cure speech disorders, speech tests using phrase materials are performed, such as choosing the optimal amplification methods, as opposed to speech tests using word stimuli, which are designed for diagnostic purposes.

Different consonants are represented by various Kurdish letters depending on their position in a word. Kurdish also uses four more letters, including (ژ (/ʒ/), چ (/tʃ/), گ (/g/), and پ (/p/). The Persian alphabet makes use of them, but the original Arabic letters do not have them. However, in rare instances, the two consonants are seen, which, for instance, has a consonant printed twice, وڵا وڵا (Waḥḥaḥ/, which stands "Swearing" in English.

(See Table 2.)

After determining hearing thresholds through calculating pure tone average (PTA) from air conduction thresholds at 0.5, 1 and 2 KHz by puretone audiometer, determine WRS monaurally in the better ear at several intensities through speech audiometer (Path medical GmbH Germany) by using monosyllable words lists through monitored live voice (MLV) with the microphone at a distance of about 15cm distance from the tester's lips which are covered by paper or mask to avoid lip-reading. The typical VU meter has a range that goes from -20 dB to +10 dB relative to the calibration point at 0 dB. Later, count the number of words that are correctly identified and convert to the percentage of the number of words presented (whole word score). Each group is tested by one half list at different intensity levels beginning at a speech level of 10 dB and increasing this level step-wise by an intensity of 10 dB until 60 dB when the subject reached maximum score in order to obtain the performance-intensity function and to assess internist intelligibility differences.

The Speech Reception Threshold (SRT) is the lowest level at which a patient can repeat 50% of spondee words. There are various methods to determine this threshold, and no single method is universally used. Commonly, spondee words are presented one at a time at the same level. In descending methods, testing starts above the estimated SRT and decreases until the patient misses enough words. In ascending methods, testing begins below the estimated SRT and increases until the patient can repeat a sufficient number of words. This procedure is repeated until the patient correctly repeats a certain number of words, at which point the ascending run is terminated.

- Pure Tone Audiometry (PTA)

Through two different paths, pure-tone testing evaluates the auditory system. Sound waves that are being tested for air conduction (AC). Enter the external auditory canal, travel via the tympanic membrane, ossicular chain, and cochlea, and then transit the auditory nerve VIII and the brainstem on their way to the auditory cortex. Through the vibration of the bone conduction oscillator on the mastoid process during bone conduction (BC) testing, sound waves are directly transmitted to the cochlea and beyond.

The components of an audiometer are shown in. The power switch controls the electrical supply to the instrument, and there is often a power indicator lamp to show whether it is on or off. Test tones are presented to the patient by turning them on and with a button called the interrupter. Choose from a variety of test frequencies using the frequency slider. 125, 250, 500, 750, 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz are included in the majority of audiometers. An audiometer component known as a pure tone oscillator creates the actual pure tones.

- Audiometer Calibration

Signals between 125 and 8000 Hz can be produced with a pure tone audiometer. Higher frequencies (8000–16,000 Hz) are covered by an expanded high-frequency audiometer. Most audiometers include the ability to generate sounds that are used to hide test signals. Examples include a bone vibrator, earphone, or loudspeaker of transducers that may transmit test signals. Other sound types, such as pulsed tones, speech sounds, frequency-modulated tones, and other sounds, may be delivered by some audiometers. The type name for an audiometer identifies its features in general.

Regarding signals and distribution methods that are readily available, a type 1 audiometer, for instance, is the most complete (American National Standard Method for Coupler Calibration of Earphones) (ANSI S3.6 2010) (Champlin & Letowski, 2014).

- Air-Conduction Calibration

To make sure that the patient is receiving the appropriate SPLs, an audiometer is calibrated using a sound level meter. Each earphone is calibrated individually for air-conduction by measuring the sounds they generate.

- Bone-Conduction Calibration

Measuring the maximal force that a bone conduction device connected to a human skull can exert is required for safety evaluation. Audiometry uses force from bone conduction vibrators, and this force and its connection to hearing level are frequently measured in accordance with American National Standards Institute standard S3.43-1992, up to 4 kHz in frequency. The Ultra Quiet employs 20 kHz of bone-conducted vibration as tinnitus treatment. In the 6 kHz to 20 kHz Ultra Quiet frequency range, there is no reference point for calibrating bone conduction force. A synthetic mastoid with this range's impedance calibration is likewise nonexistent. The Briel & Kjaer (B&K, Naerum, Denmark) 4930, for instance, has a 10 kHz calibration. In our research, in comparison to conventional audiometric values at 6 kHz from a Radio ear (New Eagle, P A) B-71 vibrator on the artificial mastoid and the live head, the Ultra Quiet system was assessed on a live human head to 20 kHz and on a B&K 4930 artificial mastoid to 10 kHz (Lenhardt et al., 2002).

-Audiological Testing Rooms

In specifically designed, sound-isolated rooms, audiological testing is carried out. Commercial audiometric booths come in two different configurations: a single chamber or suites with two rooms. A typical booth's interior is depicted through a patient's perspective. When using single-room booths, the patient remains within the booth while the tester and other equipment are outside (Flood, 2016).

However, if live-voice speech testing is taking place, the control room should be as silent as you can make it. Particularly for sound field testing and/or pediatric assessments, the patient room should be as big as it can be. The tester's space must be big enough for them to work comfortably and for an observer to join them. Usually made of 4-inch-thick panels of metal sheets packed with sound-absorbing material, the walls, ceilings, floors, and doors are all enclosed in these structures. However, fluorescent lighting can be used if care is taken to mount their noisy ballasts or starters outside the booth. To reduce reverberation, the doors should close with tight seals, and the windows between the patient and tester rooms are made of multiple panes of glass with dead air spaces between them (Flood, 2016).

Measurements of Study Tools

- Validity of the Questionnaire

The variables included in this study were obtained from previous studies in the literature. This technique helped us ensure that the variable measurements were valid for research purposes. Additionally, the questionnaire created for this study was reviewed by a panel of 7 experts specializing in various fields of medical sciences

(Appendix G) including Audiologist, ENT, Statistics and Public Health. Copies of the study questionnaire sheet were given to the experts, who were asked to examine them for clarity and adequacy of the information. Their responses revealed several comments on the questionnaire page, which were modified in response to their suggestions. The questionnaire was well organized and constructed, according to the majority of specialists.

- Reliability of the study:

In terms of the reliability, the items of the hearing loss were obtained from the literature and rated as appropriate. To find out the reliability of the questionnaire, the reliability test was performed for these items. In this regard, the Cronbach's alpha was performed for the reliability test. The Cronbach's alpha of the entire items in the hearing loss issues was 0.6514. The value equals or greater than 0.06 is considered the acceptable level for the reliability.

Statistical analysis

The general information of the patients and healthy controls were presented in mean (SD) or number (%).Hearing issues of patients with hearing loss and healthy controls were presented in number and percentage. Comparisons of degree of hearing loss between patients and controls were examined in an independent t-test. The significant level of difference was examined with a p-value of less than 0.05. The statistical calculations were performed in JMP pro 14.3.0 (JMP®, Version 14.3.0. SAS Institute Inc., Cary, NC, 1989–2023.)

Limitations of the study

During the investigation, the researcher faced limitations, including some

participants experiencing dizziness and vertigo during the test. These side effects likely affected their ability to complete the test, which could have impacted the accuracy of the results and required adjustments, such as breaks or medical attention. These challenges limited the reliability of the findings.

RESULTS

Participants who provided their consent completed the questionnaire, which typically took approximately 45 minutes to finish. The study ensured strict confidentiality and the data collected will be solely utilized for research purposes. The average age of participants in the study group was 23.34 years (4.76%), while in the control group, it was 20.20 years (1.12%). Among the sample population, approximately 66% of the study group and 52% of the control group were male, whereas 34% of the study group and 48% of the control group were female.

(See Table 3.)

Table 4 shows that there is a higher significant of the patient with hearing loss in the term “I can understand conversations even when several people are talking”, occasionally compared to the healthy control (see Table 4.). While the patient with hearing loss is a lower significant in the term “When I’m listening to the news on the car radio, and family members are talking, I have trouble hearing the news” about half the time compared to the healthy control and so on.

Table 5 presents the correlation between the patients with hearing loss and healthy controls regarding hearing loss in the right, left, and bilateral ears, as well as the types and duration of the problem. There is a lower

significant of the healthy controls in terms of right ear SNHL 0 (0%) compared to the patients 22 (44%), as well as CHL with 5 (10%) in the patient and 0 (0%) in the healthy controls, and Mixed HL there is a highly significant in left ear (see Table 5.). Additionally, there is a highly significant in the duration of the problem between the patient and healthy controls, specifically for durations of 01-11 months ago 24 (48%) for the patient, and durations of 5 years is 11 (22%) for the patient compared to healthy controls 0 (0%).

Table 6 shows the comparisons of speech issue sound detection thresholds between the patient and healthy controls for the right, left, and bilateral ears (see Table 6.). It is a significantly high of the study compared with healthy controls in the right ear sound detection threshold (SD = 82.06 (15.83)) patient and (SD = 96.8 (3.35)) healthy controls. Similarly, there is a widely significant in the left ear sound detection threshold (SD = 82.58 (14.73)) patient compared with (SD = 97.6 (2.19)) healthy controls. Additionally, there is a significant difference in the bilateral ears sound detection threshold (SD = 97.47(5.20)) patient and (SD = 99.91 (0.60)) healthy controls.

Table 7 shows that there is a strongly significant of the patient with hearing loss in term of sound detection threshold in right ear of detected threshold about 31 (62%) for patient compared to the healthy control 5 (10%). And also, there is a significantly high of the patient in left ear sound detection threshold for not detected threshold is 19 (38%) compared to the healthy control 45 (90%). While there is a lower significant of the healthy control in Bilateral ears sound detection threshold about 45% detection and

5% not detected threshold compared to the patient with hearing loss.

(See Table 7.)

Table 8 shows the comparisons of sound recognition between the patients for the right, left, and bilateral ears (see Table 8.). There is a lower significant of the healthy controls compared with patients with hearing loss in the right ear sound recognition threshold, with 3 (25%) in the patients and 0 (0%) in the healthy controls at 60dB. Similarly, there is a strongly significant in the left ear sound recognition threshold, with 10 (83.33%) in the patients and 0 (0%) in the healthy controls at 40dB. Additionally, there is a highly significant in the bilateral ears sound recognition threshold, with 6 (15.79%) in the patients and 0 (0%) in the healthy controls at 40dB.

DISCUSSION

The main findings of this study show that there is a higher significant difference in patient compared to the healthy controls in the sound detection threshold for speech issues in the right, left, and bilateral ears, as well as in sound recognition for bilateral ears. Additionally, there is a higher significant difference in hearing loss for the right and left ears. Factors strongly associated with the patient group compared to healthy controls include age, male gender, and hearing problems in the right ear, left ear, and bilateral ears. Furthermore, there is a strongly significant in the duration of the hearing problem, specifically about 10-11 months ago.

Based on the results presented in this study, there are highly significant differences observed between the patient and healthy

controls in terms of sound recognition thresholds and hearing loss. These differences could be attributed to various factors such as underlying medical conditions, exposure to loud noise, or other individual characteristics.

In agreement with the previous study, the current study, the average age in the patient with hearing loss was 23.34 years (4.76%), and in the healthy controls, it was 20.20 years (1.12%). Approximately 66% of the patient and 52% of the healthy controls were male, while 34% of the patient and 48% of the healthy controls were female. And in the Garadat et al. (2017) patient indicating that there were no differences in performance between male and female participants in the study.

The previous study included 15 healthy controls (2 males, 13 females, age 33-66 years, median age 51 years) and 15 patient (4 males, 11 females, age 34-72 years, median age 52 years) participants in the NH group showed an average score of 58% (SD = 4.3), while the average score for the HI group was 59% (SD = 3.8), a Levene's Test for Equality of Variances showed no significant difference in variance ($p = 0.405$) and a two-sided independent samples t -test for Equality of Means showed no significant difference in means ($p = 0.334$) between groups (Koelewijn et al., 2017).

Recent studies have supported current findings indicating that there is a lower significant of the healthy controls in terms of right ear CHL with 5 (10%) in the patient and 0 (0%) in the healthy controls. Previous studies show that the participants with CHL had significantly lower correct responses than individuals with normal hearing for both sides. The results suggest reduced

auditory temporal processing ability in adults with CHL compared to normal hearing subjects. Therefore, developing a clinical protocol to evaluate auditory temporal processing in this population is recommended (Bayat et al., 2017).

In contrast to the findings of this study, it shows the comparisons of sound recognition between the patients for the right, left, and bilateral ears. There is a significant difference in the left ear sound recognition threshold, with 10 (83.33%) in the patients and 0 (0%) in the healthy controls at 40dB. Additionally, there is a significant difference in the bilateral ears sound recognition threshold, with 6 (15.79%) in the patients and 0 (0%) in the healthy controls at 40dB. The Dias et al. (2015b) study shows that at 40 dB SL (above the SRT) level, normal hearing subjects attained maximum speech identification scores when compared to hearing impaired subjects using both word lists and was statistically significant ($p = 0.001$). Hence, it can be concluded that there is a significant difference in the performance of individuals with normal hearing and those with hearing impairment. Suggested that the word lists need to be tested on the population for which the test is intended in order to establish a more accurate test.

Similar to the current study, in the Bansal et al. (2016) study, out of cases, 44.55% had SNHL (bilateral - [67.95%]; unilateral - [32.04%]) which was the most common type of hearing impairment among patients complaining of HL. This study had incidence of pure USNHL in 19.32% cases of SNHL, which is higher than other studies. The higher incidence may be because of difference between the total populations being considered. While in the current study out of cases 50% had SNHL (bilateral - [19

(82.61%)]]; unilateral - [34 (68%)] there is a highly significant difference between the study and control groups.

In line with the previous study, the Marinova-Todd et al. (2011) study shows that the word recognition scores in English were significantly lower than the word recognition scores in Cantonese for both the normal-hearing ($p < 0.0001$) and hearing-impaired groups ($p < 0.0001$). On the other hand, while the English scores of the hearing-impaired group are significantly lower than those of the normal-hearing group ($p = 0.003$), there was no significant difference between the groups when tested in Cantonese ($p = 0.19$). In other words, the effect of hearing impairment was greater when tested in the second language than in the native language. But in current studies it shows the comparisons of word recognition scores in Kurdish sound detection thresholds between the patient and healthy controls for the right, left, and bilateral ears. There is a highly significant difference between the patient and healthy controls in the right ear sound detection threshold ((Patient SD = 82.06(15.83) and (health controls SD = 96.8(3.35)). Similarly, there is a high significant difference in the left ear sound detection threshold ((Patient SD = 82.58(14.73) and (health controls SD = 97.6(2.19)). Additionally, there is a significantly high difference in the bilateral ears sound detection threshold ((Patient SD = 97.47(5.20) and (health controls SD = 99.91(0.60)).

Previously published studies (Pals, 2008) show the differences in detection or recognition between the categories is highly significant. It is to ensure participants are presented with at least one, preferably two or more, sounds from each category. This will

result in more useful data from an equal number of participants. While the current study shows that there is a highly significant in the sound recognition threshold in the patient compared to the healthy controls at 40dB.

As in this study, other literature has confirmed that these measures were also significantly correlated to high-frequency hearing loss ($p < 0.001$, $p = 0.031$, $p = 0.010$). SRT and spatial advantage were also significantly correlated to low-frequency hearing loss ($p < 0.001$, $p = 0.009$). However, SRT was significantly correlated with both low-frequency hearing loss ($p = 0.007$) and high-frequency hearing loss ($p = 0.012$). Talker advantage, which is a measure of the benefit gained from access to pitch cues, was significantly correlated with high-frequency hearing loss ($p = 0.003$). Alternatively, it could be argued that the absence of an age effect in this study is because of the different materials and maskers used in the study design (Glyde et al., 2013). Quiet thresholds were found to vary between 16 and 41.5dB SPL and were not significantly correlated with age ($R^2 = 0.05$, $p > 0.05$), although quiet speech thresholds were significantly correlated with the average pure-tone thresholds at the two ears. Correlations were stronger for the average of three low- to mid-frequency thresholds (5, 1, 2 kHz: $R^2 = 0.62$, $p < 0.0001$) than for three mid- to high-frequency thresholds (1, 2, 4 kHz: $R^2 = 0.52$, $p < 0.0001$) (Gallun et al., 2013). Numerous studies revealed that the difference between normal hearing and hearing-impaired listeners was significant [$p = 0.003$]. The apparent difference between the two groups is supported by a significant interaction between hearing status and “static” versus “illusion” stimulus condition [$p < 0.001$].

These findings are argued to be primarily the result of (a) a change in dynamic binaural sensitivity and (b) high-frequency hearing loss affecting the audibility of pinna cues (Brimijoin & Akeroyd, 2016). The current study compares the ear hearing loss between the patient and healthy controls for both the right and left ears. There is a highly significant in the right ear SN hearing loss, with 22 (44%) in the patients and 0 (0%) in the healthy controls.

Consistent with the previous study, two subjects presented with a bilateral mixed hearing loss, the other two with a unilateral mixed hearing loss all the implanted subjects reached an SRT value below 65 dB, indicating that, at conversation level in quiet, more than 50% of the words could be understood. For this reason, some problems at the interposed skin level can be foreseen, especially in those patients undergoing a retroauricular incision after multiple middle ear surgeries (Barbara et al., 2013). The current study shows that the Mixed HL there is a highly significant in bilateral and unilateral hearing loss.

In contrast to the findings of the present study, Li et al. (2022) found no significant difference in the factors of duration between the two groups ($p = 0.624$) (Li et al., 2022). The possible reason for this non-significant difference may be attributed to emotional and functional dimensions in their study. However, in the current study, a highly significant difference was observed in the duration of the problem between the patient and healthy controls, specifically for durations of 01-11 months ago 24 (48%) for the patient, and durations of 5 years is 11 (22%) for the patient compared to healthy controls 0 (0%).

Numerous studies revealed that Lunner (2003) shows the correlations between hearing loss and speech reception were significant ($r=0.47-0.49$). As well as the Rudner et al. (2007), shows four of the correlations between speech test and reading span score were significant ($r=0.37-0.56$). In addition, Zekveld et al. (2007) shows that the visual text-reception threshold was significantly correlated with the auditory speech-reception thresholds in both static and modulated noise ($r=0.54-0.54$). This is often taken as a measure of working memory and predicts performance on a wide range of cognitive tasks. The current study shows that there is a significant difference between hearing loss and speech recognition threshold.

CONCLUSION

This study showed that the patients with hearing loss has significantly higher rates of speech difficulty and other audio-related issues compared to the healthy controls. In addition, the study showed that the established guideline can be used as a guide for identification of hearing loss to the Kurdish populations.

Based on the findings, the current study has significant implications for the field, as it contributes to improving audiological diagnostic and rehabilitation services in the Kurdistan Region/Iraq. By conducting thorough validation experiments, the authors propose that the developed Word Recognition Test lists can be universally applied across different countries, indicating their broad applicability in diverse cultural and linguistic contexts. Overall, the results suggest that the developed speech materials are suitable for clinical testing of speech

audiometry in the specific population, as evidenced by the consistent performance observed across the two monosyllabic word lists and the lack of differences between Speech Reception Thresholds (SRTs) and Pure Tone Averages (PTAs). These findings highlight the importance of further research to identify the underlying causes and potential interventions for individuals experiencing hearing loss. Additionally, these results emphasize the need for regular hearing screenings and interventions to prevent and manage hearing impairments in the population. Further investigation and analysis are needed to determine the specific causes and implications of these findings.

RECOMMENDATIONS

1. The created Kurdish speech test lists should be standardized in Kurdistan Region /Iraq, and depended on the Ministry of Health in Kurdistan Region /Iraq.
2. Further research is needed to explore the relationship between hearing loss and speech difficulty and quality of life (That includes aspects related to physical, mental, social, and environment interactions).
3. Providing this group of patient with counselling services in order to help them obtaining social and psychological adjustment.

REFERENCES

- Abdulhaq, N. M. A. (2006). *Speech perception test for Jordanian Arabic speaking children*. University of Florida.
- Al Matar, W. (2021). *Speech audiometry: Arabic word recognition test for adults*. Kent State University.
- Alberti, P. W. (2001). The anatomy and physiology of the ear and hearing. *Occupational exposure to noise: Evaluation, prevention, and control*, 53-62.
- Alisaputri, M. (2016). *Development of Bisyllabic Speech Audiometry Word Lists for Adult Malay Speakers* (Doctoral dissertation, De Montfort University).
- Alusi, H. A., Hinchcliffe, R., Ingham, B., Knight, J. J., & North, C. (1974). Arabic speech audiometry. *Audiology: official organ of the International Society of Audiology*, 13(3), 212-230.
- Anjos, W. T. D., Ludimila, L., Resende, L. M. D., & Costa-Guarisco, L. P. (2014). Correlation between the hearing loss classifications and speech recognition. *Revista CEFAC*, 16, 1109-1116.
- Ashoor, A. A., & Prochazka, T. (1982). Saudi Arabic speech audiometry. *Audiology*, 21(6), 493-508.
- Bansal, D., Varshney, S., Malhotra, M., Joshi, P., & Kumar, N. (2016). Unilateral sensorineural hearing loss: A retrospective study. *Indian Journal of Otology*, 22(4), 262. <https://doi.org/10.4103/0971-7749.192174>
- Barbara, M., Perotti, M., Gioia, B., Volpini, L., & Monini, S. (2013). Transcutaneous bone-conduction hearing device: audiological and surgical aspects in a first series of patients with mixed hearing loss. *Acta oto-laryngologica*, 133(10), 1058-1064.
- Bayat, A., Farhadi, M., Emamdjomeh, H., Saki, N., Mirmomeni, G., & Rahim, F. (2017). Effect of conductive hearing loss on central auditory function☆. *Brazilian journal of otorhinolaryngology*, 83, 137-141.
- Boboshko, M. Y., Zhilinskaia, E. V., Golovanova, L. E., Legostaeva, T. V., Di Berardino, F., & Cesarani, A. (2017). The use of speech audiometry in the practice of the geriatric center. *Advances in Gerontology*, 7, 166-169.
- Brimijoin, W. O., & Akeroyd, M. A. (2016). The effects of hearing impairment, age, and hearing aids on the use of self-motion for determining front/back location. *Journal of the American Academy of Audiology*, 27(07), 588-600.
- Butler, C. A. (2014). The effects of acoustically modified speech tests on the speech perception abilities of individuals with sensorineural hearing loss.
- Carhart, R. (1951). Basic principles of speech audiometry. *Acta Oto-Laryngologica*, 40(1-2), 62-71.
- Champlin, C. A., & Letowski, T. (2014, November). Audiometric calibration: Air conduction. In *Seminars in Hearing* (Vol. 35, No. 04, pp. 312-328). Thieme Medical Publishers.
- Chinnaraj, G., Neelamegarajan, D., & Ravioose, U. (2022). Development, standardization, and validation of bisyllabic phonemically balanced Tamil word test in quiet and noise. *Journal of Hearing Science*, 11(4), 42-47.
- Coene, M., van der Lee, A., & Govaerts, P. J. (2015). Spoken word recognition errors in speech audiometry: a measure of hearing performance?. *BioMed*

- Research International*, 2015(1), 932519.
- Cox, R. M., & Alexander, G. C. (1995). The abbreviated profile of hearing aid benefit. *Ear and hearing*, 16(2), 176-186.
- Cunningham, L.L., Tucci, D.L., 2017. Hearing loss in adults. *New England Journal of Medicine* 377, 2465–2473.
- De Sousa, K. C., Swanepoel, D. W., Moore, D. R., Myburgh, H. C., & Smits, C. (2020). Improving sensitivity of the digits-in-noise test using antiphasic stimuli. *Ear and Hearing*, 41(2), 442-450.
- Dias, M. A., Devadas, U., & Rajashekhar, B. (2015). Development of speech audiometry material in goan Konkani language. *Language in India*, 15(2), 268-80.
- Egan, J. P. (1944). *Articulation Testing Methods II...* Research on Sound Control, Psycho-Acoustic Laboratory, Harvard University.
- Exeter, D. J., Wu, B., Lee, A. C., & Searchfield, G. D. (2015). The projected burden of hearing loss in New Zealand (2011-2061) and the implications for the hearing health workforce. *The role of medical generalism in the New Zealand health system into the future*, 128(1419).
- Flood, L. M. (2016). *Essentials of Audiology*, 4th edn. SA Gelfand. Thieme, 2016. ISBN 978 1 60406 861 0 pp 536 Price£ 65.50€ 79.99. *The Journal of Laryngology & Otology*, 130(8), 787-787.
- Gallun, F. J., Diedesch, A. C., Kampel, S. D., & Jakien, K. M. (2013). Independent impacts of age and hearing loss on spatial release in a complex auditory environment. *Frontiers in neuroscience*, 7, 252.
- Garadat, S. N., Abdulbaqi, K. J., & Haj-Tas, M. A. (2017). The development of the University of Jordan word recognition test. *International journal of audiology*, 56(6), 424-430.
- Glyde, H., Cameron, S., Dillon, H., Hickson, L., & Seeto, M. (2013). The effects of hearing impairment and aging on spatial processing. *Ear and hearing*, 34(1), 15-28.
- Haile, L. M., Kamenov, K., Briant, P. S., Orji, A. U., Steinmetz, J. D., Abdoli, A., ... & Rao, C. R. (2021). Hearing loss prevalence and years lived with disability, 1990–2019: findings from the Global Burden of Disease Study 2019. *The Lancet*, 397(10278), 996-1009.
- Hamarashid, H. K., Saeed, S. A., & Rashid, T. A. (2021). Next word prediction based on the N-gram model for Kurdish Sorani and Kurmanji. *Neural Computing and Applications*, 33(9), 4547-4566.
- Ibelings, S., Brand, T., & Holube, I. (2022). Speech Recognition and Listening Effort of Meaningful Sentences Using Synthetic Speech. *Trends in Hearing*, 26, 23312165221130656.
- Iliadou, V. V., Chermak, G. D., & Bamiou, D. E. (2015). Differential diagnosis of speech sound disorder (phonological disorder): Audiological assessment beyond the pure-tone audiogram. *Journal of the American Academy of Audiology*, 26(04), 423-435.
- Jerger, J., & Hayes, D. (1977). Diagnostic speech audiometry. *Archives of Otolaryngology*, 103(4), 216-222..
- Jeung, S. H., Jin, B. M., & Hyun, K. Y. (2015). College Students' Hearing Ability through Pure Tone Audiometry. *International Journal of Innovative Science, Engineering and Technology*. 2, 25-32.

- Kapul, A. A., Zubova, E. I., Torgaev, S. N., & Drobchik, V. V. (2017, August). Pure-tone audiometer. In *Journal of Physics: Conference Series* (Vol. 881, No. 1, p. 012010). IOP Publishing.
- Kemaloğlu, Y. K., Kamışlı, G. Ş., & Mengü, G. (2017). Phonemic analysis of Turkish monosyllabic word lists used for speech discrimination word recognition tests. *The Turkish Journal of Ear Nose and Throat*, 27(4), 198-207.
- Kim, J. M., Na, M. S., Jung, K. H., Lee, S. H., Han, J. S., Lee, O. H., & Park, S. Y. (2016). The best-matched pure tone average and speech recognition threshold for different audiometric configurations. *Korean Journal of Otorhinolaryngology-Head and Neck Surgery*, 59(10), 725-729.
- Kim, T. S., & Chung, J. W. (2013). Evaluation of age-related hearing loss. *Korean journal of audiology*, 17(2), 50–53.
- Klangpornkun, N., Onsuwan, C., Tantibundhit, C., & Pitathawatchai, P. (2013, December). Predictions from speech banana and audiograms: Assessment of hearing deficits in Thai hearing loss patients. In *Proceedings of Meetings on Acoustics* (Vol. 20, No. 1). AIP Publishing.
- Koelewijn, T., Versfeld, N. J., & Kramer, S. E. (2017). Effects of attention on the speech reception threshold and pupil response of people with impaired and normal hearing. *Hearing Research*, 354, 56-63.
- Kramer, S., & Brown, D. K. (2021). *Audiology: science to practice*. Plural Publishing.
- Lasak, J. M., Allen, P., McVay, T., & Lewis, D. (2014). Hearing loss: diagnosis and management. *Primary Care: Clinics in Office Practice*, 41(1), 19-31.
- Lenhardt, M. L., Richards, D. G., Madsen, A. G., Goldstein, B. A., Shulman, A., & Guinta, R. (2002). Measurement of bone conduction levels for high frequencies. *International Tinnitus Journal*, 8(1), 9-12.
- Li, J., Qiu, Z., Qiu, Y., Li, L., Zheng, Y., Zhao, F., ... & Ou, Y. (2022). Prognostic factors influencing the tinnitus improvement after idiopathic sudden sensorineural hearing loss treatment. *Otology & Neurotology*, 43(6), e613-e619.
- Littler, T. S. (2013). *The Physics of the Ear: International Series of Monographs on Physics* (Vol. 3). Elsevier.
- Lunner, T. (2003). Cognitive function in relation to hearing aid use. *International journal of audiology*, 42, S49-S58.
- Ma, X., McPherson, B., & Ma, L. (2013). Chinese speech audiometry material: Past, present, future. *Hearing, Balance and Communication*, 11(2), 52-63.
- MacLennan-Smith, F., Swanepoel, D. W., & Hall III, J. W. (2013). Validity of diagnostic pure-tone audiometry without a sound-treated environment in older adults. *International journal of audiology*, 52(2), 66-73.
- Margolis, R. H., & Popelka, G. R. (2014, November). Bone-conduction calibration. In *Seminars in Hearing* (Vol. 35, No. 04, pp. 329-345). Thieme Medical Publishers.
- Marinova-Todd, S. H., Siu, C. K., & Jenstad, L. M. (2011). Speech audiometry with non-native English speakers: The use of digits and Cantonese words as stimuli. *Canadian Journal of Speech-Language Pathology & Audiology*, 35(3).
- Masalski, M., & Kręcicki, T. (2013). Self-test web-based pure-tone audiometry: Younes, H. M. (2024). Assessing of hearing loss impacts on speech difficulties using speech audiometry. SAERA - School of Advanced Education, Research and Accreditation.

- validity evaluation and measurement error analysis. *Journal of Medical Internet Research*, 15(4), e2222.
- McArdle, R. A., Wilson, R. H., & Burks, C. A. (2005). Speech recognition in multitalker babble using digits, words, and sentences. *Journal of the American Academy of Audiology*, 16(9), 726-739.
- Meister, F. J. (2018). The Text and Metre of Sapph. fr. 114 V. *Mnemosyne*, 72(1), 1-11.
- Messouak, A. H. (1956). *Audiométrie vocale en arabe maghrébin: par Hadi Messouak...* Compagnie française d'audiologie.
- Miller, G. A., Heise, G. A., & Lichten, W. (1951). The intelligibility of speech as a function of the context of the test materials. *Journal of experimental psychology*, 41(5), 329.
- Møller, A. R. (2012). *Hearing: anatomy, physiology, and disorders of the auditory system*. Plural Publishing.
- Morgenstern, J., Lailach, S., Zahnert, T., & Neudert, M. (2020). Outcome parameters in speech audiometry: retrospective analysis of data and reporting quality in clinical studies. *European Archives of Oto-Rhino-Laryngology*, 277, 669-677.
- Musiek, F. E., & Baran, J. A. (2018). *The auditory system: Anatomy, physiology, and clinical correlates*. Plural Publishing.
- Najem, F. J., & Marie, B. (2021). Phonemically balanced Arabic monosyllabic word lists for speech audiometry testing in Jordan. *Journal of the American Academy of Audiology*, 32(04), 246-253.
- Nisar, S., Tariq, M., Adeel, A., Gogate, M., & Hussain, A. (2019). Cognitively inspired feature extraction and speech recognition for automated hearing loss testing. *Cognitive Computation*, 11, 489-502.
- Nissen, S. L., Harris, R. W., Channell, R. W., Conklin, B., Kim, M., & Wong, L. (2011). The development of psychometrically equivalent Cantonese speech audiometry materials. *International journal of audiology*, 50(3), 191-201.
- Nissen, S. L., Harris, R. W., Jennings, L. J., Eggett, D. L., & Buck, H. (2005). Psychometrically equivalent mandarin bisyllabic speech discrimination materials spoken by male and female talkers: Materiales de discriminación del lenguaje con bisilábicos en Madarín psicométricamente equivalentes utilizados por hablantes del sexo masculino y femenino. *International Journal of Audiology*, 44(7), 379-390.
- Nuesse, T., Wiercinski, B., Brand, T., & Holube, I. (2019). Measuring speech recognition with a matrix test using synthetic speech. *Trends in Hearing*, 23, 2331216519862982.
- Øygarden, J. (2009). Norwegian speech audiometry. PhD thesis, NTNU, Trondheim.
- Pals, C. (2008). *Detection and Recognition Threshold of Sound Sources in Noise* (Doctoral dissertation, Faculty of Science and Engineering).
- Parmar, B. J., Rajasingam, S. L., Bizley, J. K., & Vickers, D. A. (2022). Factors affecting the use of speech testing in adult audiology. *American journal of audiology*, 31(3), 528-540.
- Punch, J., & Rakerd, B. (2019). Evaluation of a protocol for integrated speech audiometry. *American Journal of Audiology*, 28(1), 26-36.
- Ratnanather, J. T., Wang, L. C., Bae, S. H., O'Neill, E. R., Sagi, E., & Tward, D. J.

- (2022). Visualization of speech perception analysis via phoneme alignment: a pilot study. *Frontiers in Neurology*, 12, 724800.
- Ristovska, L., Jachova, Z., Kovačević, J., & Hasanbegovic, H. (2022). Development of Macedonian monosyllabic and disyllabic tests for speech audiometry. *Human Research in Rehabilitation (HRR)*, 12(1), 27-35.
- Roßbach, J., Kollmeier, B., Meyer, B.T., 2022. A model of speech recognition for hearing-impaired listeners based on deep learning. *The Journal of the Acoustical Society of America* 151, 1417–1427.
- Rudner, M., Foo, C., Rönnberg, J., & Lunner, T. (2007). Phonological Mismatch Makes Aided Speech Recognition in Noise Cognitively Taxing: Retracted Article. *Ear and Hearing*, 28(6), 879-892.

APPENDIX

Figure 1.

Frequency in cycles per second (Klangpornkun et al., 2013).

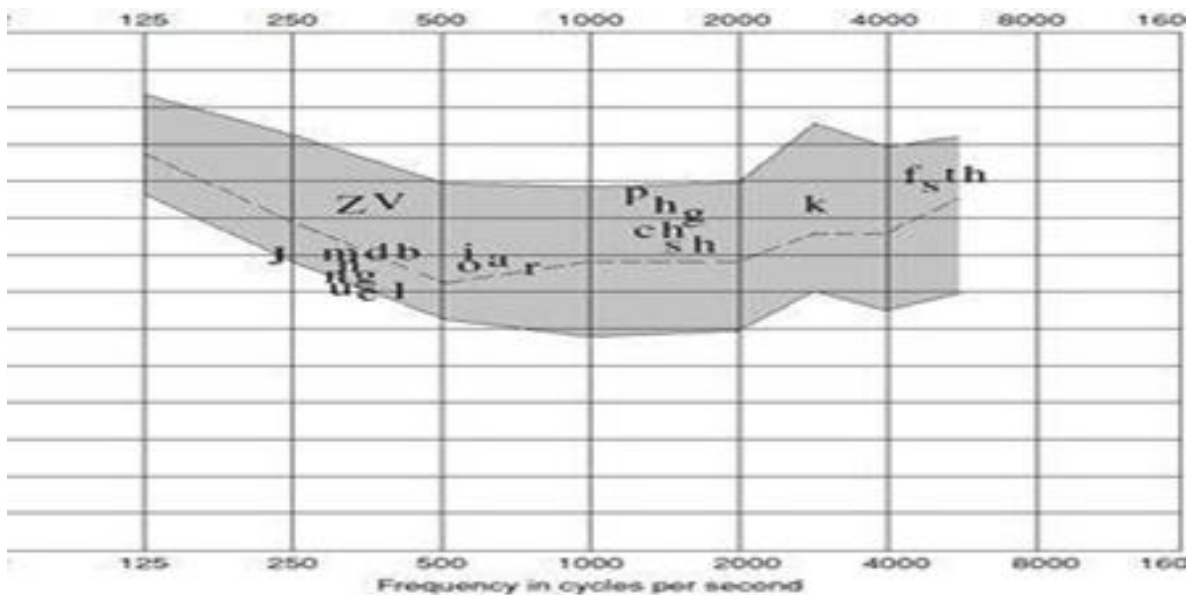


Table 1.

Vowels in Kurdish

IPA	Kurmanji	Sorani	English word examples
I	î	ى	"seat"
ɪ	î	-	"sit"
E	e, ê	ئ	"bed"
(ɛ)	e	ه	"bet"
(ə)	(mixed)	ا ه	"but"
Æ	â	ه	"cat"
U	û	وو	"moon"
ʊ	u	و	"cook"
O	o	ۆ	"got"
ɑ	a	ا	"calm"

Table 2.

Consonants in Kurdish

IPA	Kurmanji	Sorani	English word Examples	Sorani Word Examples
b	B	ب	b = "buy"	(wing) bał بآل
p	P	پ	p = "peek"	(wide) pan پان
t	T	ت	t = "time"	(crown) taj تآ
d	D	د	d = "deer"	(tree) dar دار
k	K	ك	c = "cat"	(cough) koka كه كوكا
g	G	گ	g = "green"	(bull) ga گآ
q	Q	ق	English but sounds deeper in the throat in Similar to K	(deep) qûl قوول

Table 3.

Demographic characteristics between the patient and healthy controls

Demographic characteristics	Patient (n=50)	Health controls(n=50)
Age Mean (SD)	33 (66) 17 (34)	23.34 (4.76) 20.20 (1.12)
Gender no (%)		
Male	33 (66)	26 (52)
Female	17 (34)	24 (48)

Table 4.

Hearing issues for patients with hearing loss

	Statistics of hearing loss no (%)						
Hearing issues	Always	Almost always	Generally	Half the time	Occasionally	Rarely	Never
I miss a lot of information when I'm listening to a lecture.	2 (4.00)	2 (4.00)	1 (2.00)	3 (6.00)	8 (16.00)	16 (32.00)	18 (36.00)
	1 (2.00)	5 (10.00)	6 (12.00)	6 (12.00)	9 (18.00)	16 (32.00)	7 (14.00)
Unexpected sound, like alarm bell are uncomfortable.	6 (12.00)	6 (12.00)	3 (6.00)	1 (2.00)	8 (16.00)	18 (36.00)	8 (16.00)
	7 (14.00)	2 (4.00)	7 (14.00)	7 (14.00)	8 (16.00)	12 (24.00)	7 (14.00)
I have difficulty hearing a conversation when I'm with one of my family at home.	1 (2.00)	1 (2.00)	1 (2.00)	7 (14.00)	5 (10.00)	9 (18.00)	26 (52.00)
	2 (4.00)	1 (2.00)	0 (0.00)	1 (2.00)	2 (4.00)	11 (22.00)	33 (66.00)
When I'm listening to the news on the car radio, and family members are talking, I have trouble hearing the news.	1 (2.00)	8 (16.00)	3 (6.00)	4 (8.00)	12 (24.00)	5 (10.00)	17 (34.00)
	1 (2.00)	3 (6.00)	5 (10.00)	4 (8.00)	15 (30.00)	8 (16.00)	14 (28.00)

Table 5.

Comparisons of types and duration of hearing loss between patient and healthy controls

Hearing loss	No (%)	
	Patients (n=50)	Health controls (n=50)
Hearing problem of right ear		
Normal	22 (44)	50 (100)
SNHL	22 (44)	0 (0)
CHL	5 (10)	0 (0)
MHL	1 (2)	0 (0)
Hearing problem of left ear		
Normal	7 (14)	50 (100)
SNHL	34 (68)	0 (0)
CHL	2 (4)	0 (0)
MHL	7 (14)	0 (0)
Hearing problem of bilateral ears		
Normal	0 (0)	50 (100)
SNHL	19(82.61)	0 (0)
CHL	2 (8.70)	0 (0)
MHL	2 (8.70)	0 (0)
Duration of hearing problem		
No Problem	0 (0)	50 (100)
1-3 weeks ago	3 (6)	0 (0)
1-11 months ago	24 (48)	0 (0)
1-5 years ago	12 (24)	0 (0)
5 years and over	11 (22)	0 (0)

Table 6.

Speech issues

<i>Speech issue</i>	<i>Mean (SD)</i>	
	<i>Patient (n=50)</i>	<i>Health controls (n=50)</i>
<i>Sound Detection Threshold Rt ear</i>	82.06 (15.83)	96.8 (3.35)
<i>Sound Detection Threshold Lt ear</i>	82.58 (14.73)	97.6 (2.19)
<i>Sound Detection Threshold Bilateral ears</i>	97.47 (5.20)	99.91 (0.60)

Table 7.

Detection of sound between patients and healthy controls

<i>Speech issue</i>	<i>No (%)</i>	
	<i>Patients (n=50)</i>	<i>Health controls (n=50)</i>
Sound Detection Threshold Rt ear		
Detected	31 (62.00)	5 (10.00)
Not-detected	19 (38.00)	45 (90.00)
Sound Detection Threshold Lt ear		
Detected	31 (62.00)	5 (10.00)
Not-detected	19 (38.00)	45 (90.00)
Sound Detection Threshold Bilateral ears		
Detected	19 (38.00)	45 (90.00)
Not-detected	31 (62.00)	5 (10.00)

Table 8.

Comparisons of Sound Recognition between patient and healthy controls

Sound recognition	No (%)	
	Patient (n=50)	Healthy controls(n=50)
Sound Recognition Threshold Rt ear		
20dB	7 (58.33)	0 (0)
40dB	2 (16.67)	0 (0)
60dB	3 (25)	0 (0)
Sound Recognition Threshold Lt ear		
20dB	2 (16.67)	0 (0)
40dB	10 (83.33)	0 (0)
Sound Recognition Threshold Bilateral ears		
20dB		
30dB	25 (65.79)	50 (100)
40dB	3 (7.89)	0 (0)
60dB	6 (15.79)	0 (0)
85dB	3 (7.89)	0 (0)
	1 (2.63)	0 (0)