# Speech Identification Test in Telugu: Considerations for Sloping High Frequency Hearing Loss

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**Abstract:** The present study developed two high frequency word lists (HFWLs) with each list consisting of 25 words for assessing individuals with sloping high frequency hearing loss (SHFHL). Speech identification score (SIS) testing was carried out on normal hearing subjects who were equally divided into three groups. The results revealed that there was no significant difference ($p>0.05$) in mean SIS of each group between two lists, and between three groups for each list. The groups' mean SISs were 99.68% and 99.60% for two lists respectively which are in the normal range of SIS. In order to check the applicability of HFWLs, SIS testing was carried out on subjects with sensorineural hearing loss who were equally divided into two groups. Group I: Individuals with flat frequency hearing loss (FFHL-Group). Group II: Individuals with sloping high frequency hearing loss (SHFHL-Group). SIS testing was carried out using four conventional word lists (CWLs) already existing in Telugu and two HFWLs developed in the present study. The results revealed that there was no significant difference ($p>0.05$) in mean SIS between CWLs and HFWLs in FFHL-Group. However, there was a significant difference ($p<0.05$) in mean SIS between CWLs and HFWLs in SHFHL-Group. SHFHL-Group obtained significantly lower ($p<0.05$) mean SIS for HFWLs compared to CWLs. Hence it can be concluded that CWLs would not indicate true nature of communication difficulties caused by SHFHL. On the other hand, the developed HFWLs were found be effective in identifying the true nature of communication difficulties caused by SHFHL.

**Keywords:** Speech identification test, sloping high frequency hearing loss, flat frequency hearing loss, high frequency word lists, conventional word lists, speech identification score.

## INTRODUCTION

Speech perception is the process by which the sounds of a language are heard, interpreted and understood. 'Speech perception' is defined as the receptive language process in which the input signal is speech. 'Hearing' is one of the sensory processes that may be used in speech perception. Thus "speech perception is a particular form of receptive language processing and hearing is a particular sensory modality contributing to speech perception" [1]. It is clear that speech is one of the most important media of human communication system as speech sounds are more meaningful and reflect the critical activities of life and the source for social communication. A good auditory integrity is required in order to hear, interpret and understand speech.

The consonants are produced with the obstruction to the airflow and hence, articulatory phonetics classifies them according to whether they are voiced or voiceless, their manner of articulation (e.g. stops, fricatives, nasals, etc.) and their place of articulation (e.g. labial, alveolar, palatal, etc.). In contrast vowels are produced without obstruction to the airflow and hence, they are classified according to tongue height (high, mid and low), position of the tongue (front, central and back), lip rounding (rounded and unrounded), and duration of vowel (long and short). On the other hand acoustic phonetics describes vowels and consonants in terms of their acoustic parameters such as frequency composition, relative intensities and changes in duration. Vowels are voiced and relatively high in intensity than consonants. Vowels are produced with relatively open vocal tract with prominent resonance. The first two formant frequencies (F1 & F2) are essential for the discrimination of vowels. Vowels are more accessible to auditory analysis as they are longer in duration and may hold longer duration in the auditory memory [2]. On the other hand most of the consonants contain much less power than vowels. They are affected by loss of intensity more rapidly than vowels. They are less accessible to auditory analysis due to their brevity and relatively low intensity, and held briefly in auditory memory. Hence, vowels are relatively perceived better than consonants. However, consonants play a major role in speech intelligibility [2]. Among the consonants, voiceless consonants contain little energy than voiced consonants that they often fall even below normal hearing thresholds in average rapid conversation [3]. The identification of these consonants is more dependent upon the ability to receive the higher frequency components which are frequently missed by individuals with sensorineural hearing loss [2].

Acoustically, conversational speech has the most energy concentration approximately between 500 Hz

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and 3000 Hz, and this frequency region is most important for understanding speech, particularly when speech is meaningful [4]. Studies have shown that information in the frequencies above 2000 Hz to be significant for understanding speech in the presence of background noise [5, 6]. Similarly, Sher and Owens [7] reported that the acoustic cues above 2 KHz are necessary for discriminating words in isolation that contain high frequency phonemes. It was also reported that the acoustic cues above 2 KHz are necessary to extract meaning even from highly contextual sentences when the redundant nature of acoustic, grammatical, lexical, linguistic, and prosodic content of such sentences is reduced by distortion. In addition, Pascoe [8] suggested that the frequency range between 2500 Hz and 6300 Hz to be critical to have a significant effect on word recognition, particularly in the presence of background noise. The spectral analysis of voiceless consonants from the speech samples of adults suggested that fricatives have the highest spectral peak as compared to other phonemes. Although other voiceless phonemes have less pronounced peaks in their respective spectra, they have significant spectral energy located at higher frequencies with rising spectral slope above 1600Hz [9]. Hence, one needs to have good auditory integrity at all frequencies for good speech perception. Therefore there is a need to assess the integrity of auditory system in order to know how hearing impairment affects the ability of an individual to perceive speech. In order to find out how an individual hears, interprets and understands speech involves testing him with speech stimuli, known as speech audiometry [10].

Speech audiometry has become a fundamental tool in audiological assessment and must be performed routinely using valid and reliable clinical assessment procedures appropriate for different population. There are two common measures in speech audiometry for the diagnosis of auditory disorders. The first is “speech recognition threshold (SRT)” i.e. the threshold for the recognition of speech stimuli to provide an estimate of auditory sensitivity, as measured by pure-tone audiometry. The second is “speech recognition score (SRS) or speech identification score (SIS)” i.e. the maximum speech recognition performance in percentage obtained for speech stimuli presented at comfortable supra-threshold level [10]. The SIS testing has been used in every phase of audiology to describe the extent of communication problems created by hearing impairment; differentially diagnose cochlear and retrocochlear auditory disorders; determine the need for hearing aids and other forms of aural rehabilitation devices like cochlear implants; make comparisons between various hearing aids, amplification approaches and other forms of aural rehabilitation devices; verify their benefits; and monitor patient’s performance during diagnosis and rehabilitative processes [10].

With regards to the history of materials used for speech audiometry, variety of materials has been developed by several investigators in English and other languages including Indian languages. These speech identification tests consists of word lists which have been developed by considering phonemic balance, and are known as phonemically balanced word lists or conventional word lists. The phonemes upon which the conventional word lists are constructed are based on the frequency of occurrence of phonemes in a representative sample of speech of a particular language. That is, the phonemes in each word list occur with the same relative frequency as they do occur in a representative sample of speech of a particular language [11]. Although, the frequency of occurrence of each phoneme in the conventional word lists varies, these word lists contain almost all the phonemes (both voiced and voiceless) of a language. Speech identification assessments should measure the individuals’ ability to understand speech, and provide some estimate of the degree of communication disabilities caused by hearing loss [12]. However, many individuals with sensorineural hearing loss often do not manifest reduced speech identification performance when assessed with conventional speech identification tests. This is particularly evident when speech identification performance is assessed in individuals with sloping high frequency hearing loss (SHFHL). This is because; the effect of hearing loss on communication ability mainly depends on type, degree and configuration of hearing loss [8, 13]. The SHFHLs are the most challenging configurations that audiologists face [14]. Individuals with SHFHL would have difficulties mainly in hearing speech sounds having energy concentration in the higher frequency regions i.e. above 1000 Hz [15, 16]. Hence, they have more difficulties in perceiving voiceless consonants [13] since voiceless consonants have spectral energy above 1000 Hz [9], and contain little acoustic energy than voiced consonants in average rapid conversation [3]. In addition individuals with SHFHL would have difficulties in perceiving vowels /i/ and /e/ as their second and third formant frequencies (F2 and F3) are higher than that of other vowels [17].

Hence, there is a need to utilize speech identification tests that are able to ideally reflect the perceptual difficulties of individuals with SHFHL. A test which is not specifically designed for them would not be sensitive to identify their perceptual difficulties. The conventional speech identification tests administered during routine audiological evaluation would provide redundant information and overestimate the performance of individuals with SHFHL due to normal or near normal perception of the low-frequency speech cues. Hence, they are sensitive in determining the nature of communication problems caused by flat frequency hearing loss (FFHL), but not sensitive enough in identifying the true nature of communication problems caused by SHFHL [18].

The first speech identification test in English for individuals with SHFHL was developed by [13]. The researcher developed two word lists by considering words that contained a predominance of high-frequency consonants, which are frequently missed by individuals with sensorineural hearing loss. Each word list consisted of 25 monosyllabic words composed of voiceless consonants /p, ṭ, k, s, f, t, h/ with the vowel /I/. Although, these word lists were originally designed to make comparisons between the performances of various hearing aids, later they were reported to be useful for other clinical purposes. Similarly Pascoe [8] developed 50 monosyllabic words for assessing speech identification performance of individuals with SHFHL in English. These word lists consisted of monosyllabic words, in which about 63% of the consonants were voiceless fricatives and plosives. Hence, the word lists constructed with voiceless phonemes would be ideal in assessing the true communication difficulties caused by SHFHL, as these phonemes have spectral energy distributed predominantly in the frequencies above 1000 Hz [9].

Telugu, a South Central Dravidian language, is one of the 23 scheduled languages recognized by the Constitution of India. Telugu has the third largest number of native speakers in India and thirteenth largest number of native speakers worldwide. It is the official language of the states Andhra Pradesh and Telangana, and the mother tongue of the majority of people of two states. With reference to Telugu, Kumar and Mohanty [19] developed four word lists for assessing speech recognition performance of adults. Each word list consists of 25 words having CVCV structure. The phonemes upon which these word lists were constructed were according to the frequency of occurrence of phonemes in Telugu. Although, the frequency of occurrence of each phoneme in these word lists varies, these word lists contain almost all the phonemes of Telugu. The words containing voiced consonants would provide redundant information to individuals with SHFHL and overestimate the performance due to near normal or better perception of low frequency speech cues. Thus, it is expected that these word lists would be sensitive in identifying the true nature of communication difficulties caused by FFHL, but not in identifying the true nature of communication difficulties caused by SHFHL. No such materials are available with reference to Telugu for assessing individuals with SHFHL. Hence the present study aimed to develop speech identification test in Telugu for assessing individuals with SHFHL by considering words composed of voiceless consonants.

## METHOD

The study was conducted in the following three phases: 1) Development of speech identification test for assessing individuals with SHFHL. 2) Establishment of normative data. 3) Checking the applicability of the developed test on clinical population.

### Development of Speech Identification Test

The development of speech identification test for assessing individuals with SHFHL was conducted in the following four phases: 1) Collection of disyllabic words composed of voiceless consonants. 2) Familiarity assessment of collected words. 3) Content validation of most familiar words. 4) Construction of speech identification test.

#### *Collection of Disyllabic Words in Telugu*

The disyllabic words in Telugu composed of voiceless consonants /k, c, ṭ, t, p, ś, ṣ, s, h/ were collected from different sources like periodicals, newspapers, magazines, journals, general books, phonetic books and spontaneous speech. These words were subjected to familiarity assessment.

#### *Familiarity Assessment*

The collected words were assessed for familiarity in order to ensure that these were known to native speakers of Telugu and were commonly used by people belonging to different regions of Andhra Pradesh and Telangana states. A total of 150 subjects who are native speakers of Telugu in the age range between 18 and 35 years from Coastal Andhra, Rayalaseema and Telangana regions were included in

order to assess familiarity of words. The subjects were further equally subdivided into three groups based on the above mentioned regions. A three-point rating scale was used for familiarity rating: most familiar, familiar and unfamiliar. The subjects were explained about the ratings as follows:

- Most familiar: A word should be rated as 'most familiar' if the subject knows the meaning of that word and he/she uses the same word to express in a day-to-day basis.
- Familiar: A word should be rated as 'familiar' if the subject knows the meaning of that word but he/she uses an alternative word to express in the daily activities.
- Unfamiliar: A word should be rated as 'unfamiliar' if the subject is not aware of it.

The responses of the subjects were scored based on three-point rating scale, i.e. the words which were rated as most familiar, familiar and unfamiliar were assigned a score of 2, 1 and 0 respectively. Based on the subjects' ratings, a word-wise total score was calculated and converted into percentage. The words with 90% score and more were selected for each group and further assessed for homogeneity across groups. These words were considered for further assessment.

### *Validation of Most Familiar Words*

Content validity was carried out in order to review how the essential test items (words) can attribute to the test measures. The most familiar and commonly used words were given to five experts working in the field of Speech Language Pathology, Audiology, and Linguistics in order to carry out the content validity test. The experts were informed about the purpose of the test procedure and asked to respond whether the words selected would fulfil the purpose. Their responses were elicited under the categories of "use the word" and "do not use the word". A word-wise validation was carried out by each expert. The words which were agreed by each expert were selected and listed separately. These words were further assessed for homogeneity across the responses of the experts. The words which were commonly agreed by all the experts were listed separately and this pool of words served as foundation for developing speech identification test in Telugu for assessing individuals with SHFHL.

### *Construction of Speech Identification Test for Individuals with SHFHL*

The present study targeted to develop two word lists with each list consisting of 25 disyllabic words in CVCV structure. In order to achieve this target we have initially constructed one word list by randomly selecting words from the existing pool of words which were agreed by the experts. The overall frequency of occurrence of each voiceless consonant was calculated from this word list. A second word list was then constructed ensuring that both the list have same distribution of each voiceless consonant (see appendix for two word lists transcribed with broad transcription system). Each word list was composed with 84% voiceless consonants. Each list consists of 17 words composed with voiceless consonant–vowel–voiceless consonant structure, e.g. /kōti/, /cūpu/, /ṭōpĪ/, /cāpa/, /pāta/, /sāku/, /cāṭa/ etc., and remaining words in either voiced consonant–vowel–voiceless consonant, e.g. /gēṭu/, /dōśa/, /guha/, /gĪta/ etc. or voiceless consonant–vowel–voiced consonant, e.g. /kōḍi/, /sūdi/, /cēdu/, /cĪma/ etc. All the words were disyllabic in CVCV structure except the word /sañci/ 'bag' which has CVCCV structure (included in list 2). Each word list was spoken by adult female native speaker of Telugu and recorded in a sound treated room. The inter stimulus interval between the two words was set to 5 seconds. The recorded material was then edited to carry out noise and hiss reduction. Amplitude normalization of the signals was done to maintain the constant amplitude across the words. A calibration tone of 1 KHz was inserted before beginning of the word list to adjust the vu meter at zero. The word lists were then copied onto an audio compact disc using a compact disc writer. This is how we have constructed the speech identification test in Telugu that was composed of two word lists for assessing individuals with SHFHL.

Each randomized word list was spoken by a female native speaker of Telugu, and was recorded using 16 KHz sampling rate and 16 bit quantization using computerized speech lab (CSL) 4500 software. The signal was digitized at a sampling rate of 16 KHZ using a 12 bit analog to digital converter housed within the computer. Each word was saved as a separate file. The recorded material was then edited to carry out noise and hiss reduction. Amplitude normalization of the signals was done using adobe audition (version 3.0) software to maintain the constant amplitude across the words. The inter stimulus interval between the two words was set to 4 seconds. A calibration tone of 1 KHz was inserted before beginning of the word list to

adjust the vu meter at zero. The material was then copied onto an audio compact disc using a compact disc writer.

### Establishment of Normative Data

#### *Participants*

A total of 150 subjects in the age range 18 and 35 (mean age of 24.8 years) participated as subjects. The subjects were normal hearing without any speech disorder. All the subjects were native speakers of Telugu belonging to Coastal Andhra, Rayalaseema and Telangana regions. The subjects were further equally divided into three groups based on the above mentioned regions.

#### *Procedure*

All the tests were conducted in a sound treated room where the ambient noise levels were within permissible limits. The audiometric assessments including otoscopic examination, pure-tone audiometry and tympanometry were conducted to ensure that suitable subjects with normal hearing were selected. The speech identification score (SIS) testing was carried out on each subject with two word lists. The stimulus was played through a CD player, which was routed through dual channel diagnostic clinical audiometer and delivered through the TDH 39 headphones. The stimulus was presented at most comfortable level of subjects. All the subjects were tested monaurally with two word lists and ear selection was done randomly. An open-set response in the form of an oral response was obtained. If the subject felt tired during the test, a short break was given. Each subject was given following instructions in Telugu "you will listen to the words presented one after another through headphones. Listen carefully and when you hear a word repeat the word in a loud voice". Initially ten practice items were presented in order to familiarize the subjects with the test procedure.

The responses of the subjects were marked as either 0 or 1. Each correct response was given a score of 1 and an incorrect response was given a score of 0. The raw score was then converted to percentage which is known as SIS. The SIS was calculated for each subject for each word list separately. The mean SIS values obtained by subjects of each group for two word lists were calculated.

$$\text{SIS}\,(\%) = \frac{\text{Total number of correct response}}{\text{Total number of words presented}} \times 100$$

#### *Statistical Analysis*

The data were subjected to one-way ANOVA in order to find out the significant difference in mean SIS of each group between the two words lists, and mean SIS for each word list between three groups.

### Checking the Applicability on Clinical Population

#### *Participants*

A total of 50 individuals with sensorineural hearing loss who were native speakers of Telugu participated as subjects. The subjects were further equally divided into two groups. Group I: consisted of subjects with bilateral symmetrical moderate to moderately severe flat frequency hearing loss (FFHL-Group). Group II: consisted of subjects with bilateral symmetrical sloping high frequency hearing loss (SHFHL-Group) with the

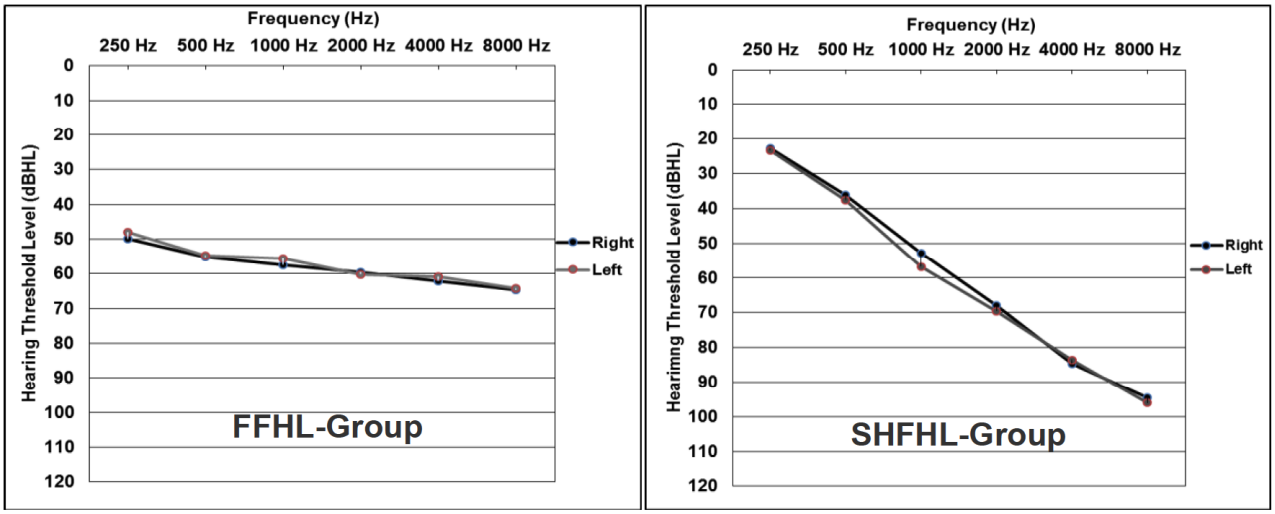


**Figure 1:** Mean air conduction pure-tone thresholds of two groups.

audiogram pattern of gradually sloping, sharply sloping, or a precipitously sloping configuration. The mean air conduction pure-tone thresholds of both the groups are shown in Figure **1**.

### *Procedure*

All the tests were conducted in a sound treated room where the ambient noise levels were within permissible limits. The audiometric assessments including otoscopic examination, pure-tone audiometry, speech audiometry and tympanometry were conducted to ensure that suitable subjects were selected for the study. The speech identification score (SIS) testing was carried out at most comfortable level on each subject with four conventional word lists (CWL-1, CWL-2, CWL-3 and CWL-4) developed by [19], and two high frequency word lists (HFWL-1 and HFWL-2) developed in the present study. The rest of the procedure remained same as it was done on normal hearing subjects. The mean SIS obtained by subjects of each group for six word lists (i.e. four CWLs and two HFWLs) were calculated.

### *Statistical Analysis*

The data were subjected to one-way ANOVA in order to find out the significant difference in mean SIS of each group between six word lists.

## RESULTS

The mean and standard deviation values of SIS obtained by three groups (i.e. native speakers of Telugu belonging to Coastal Andhra (Group I), Rayalaseema (Group II) and Telangana (Group III) for two word lists (i.e. HFWL-1 and HFWL-2) were calculated for each group and summarized in Table **1**.

The mean and standard deviation values of SIS obtained by three groups for HFWL-1 and HFWL-2 were subjected to one-way ANOVA in order to find out significant difference in mean SIS between two word lists for each group, and between three groups for each word list. The results indicated that there was no statistically significant difference ($p>0.05$) in mean SIS between two word lists for each group, and between the three groups for each word list. Hence, it can be concluded that the four word lists developed were equally difficult for all the groups and can be used interchangeably.

In order to check the applicability of developed word lists (HFWL-1 and HFWL-2), SIS testing was carried out on flat frequency hearing loss group (FFHL-Group) and sloping high frequency hearing loss group (SHFHL-Group). The mean and standard deviation values of SIS obtained by two groups for four CWLs (CWL-1, CWL-2, CWL-3 and CWL-4) and two HFWLs

**Table 1: Mean and SD Values of SIS Obtained by Three Groups for Two Lists**

| Group | Speech Identification Score (%) | | | |
|---|---|---|---|---|
| | List 1 (HFWL-1) | | List 2 (HFWL-2) | |
| | Mean | SD | Mean | SD |
| Group I | 99.68 | 1.09 | 99.76 | 1.20 |
| Group II | 99.52 | 1.31 | 99.44 | 1.40 |
| Group III | 99.84 | 1.08 | 99.60 | 1.21 |

**Table 2: Mean and SD Values of SIS Obtained by Two Groups for Six Word Lists**

| Word List | Speech Identification Score (%) | | | |
|---|---|---|---|---|
| | FFHL-Group | | SHFHL-Group | |
| | Mean | SD | Mean | SD |
| CWL-1 | 80.83 | 4.46 | 75.83 | 4.93 |
| CWL-2 | 80.33 | 6.00 | 75.50 | 5.39 |
| CWL-3 | 80.66 | 5.49 | 75.66 | 6.23 |
| CWL-4 | 80.50 | 6.05 | 75.33 | 5.85 |
| HFWL-1 | 79.66 | 5.52 | 59.50 | 4.13 |
| HFWL-2 | 79.83 | 5.33 | 59.75 | 4.26 |

(HFWL-1 and HFWL-2) were calculated and summarized in Table **2**.

The FFHL-Group obtained mean SIS of 80.83%, 80.33%, 80.66% and 80.50% for CWL-1, CWL-2, CWL-3 and CWL-4 respectively. On the other hand this group obtained a mean SIS of 79.66% and 79.83% for HFWL-1 and HFWL-2 respectively. The data was subjected to one-way ANOVA in order to find out significant difference in mean SIS between six word lists for FFHL-Group. The results indicated that there was no statistically significant difference ($p>0.05$) in FFHL-Group's mean SIS between six word lists. Hence, it can be concluded that the CWLs and HFWLs are considered equivalent in assessing the communication difficulties caused by FFHL.

Similarly, the SHFHL-Group obtained mean SIS of 75.83%, 75.50%, 75.66% and 75.33% for CWL-1, CWL-2, CWL-3 and CWL-4 respectively. On the other hand this group obtained a mean SIS of 59.50% and 59.75% for HFWL-1 and HFWL-2 respectively. It was noticed that the SHFHL-Group obtained higher SIS for CWLs as compared to HFWLs. The data were subjected to one-way ANOVA in order to find out significant difference in mean SIS between six word lists for HFSHL-Group. The results indicated that there was a statistically significant difference ($p<0.05$) in HFSHL-Group's mean SIS between and within the six word lists. Hence, the data was further subjected to LSD-post hoc analysis in order to find out significant difference in mean SIS between six word lists.

The results revealed that there was no statistically significant difference ($p>0.05$) in mean SIS between four CWLs (i.e. between CWL-1 and CWL-2, CWL-1 and CWL-3, CWL-1 and CWL-4, CWL-2 and CWL-3, CWL-2 and CWL-4, CWL-3 and CWL-4). Similarly, there was no statistically significant difference ($p>0.05$) in mean SIS between two HFWLs (i.e. between HFWL-1 and HFWL-2). However, the results further revealed that there was a statistically significant difference ($p<0.05$) in mean SIS between CWLs and HFWLs (i.e. between CWL-1 and HFWL-1, CWL-1 and HFWL-2, CWL-2 and HFWL-1, CWL-2 and HFWL-2, CWL-3 and HFWL-1, CWL-3 and HFWL-2, CWL-4 and HFWL-1, and CWL-4 and HFWL-2). Hence it can be concluded that the CWLs overestimatethe performance of individuals with SHFHL and do not indicate the true nature of communication difficulties caused by SHFHL. On the other hand it was observed that HFWLs are more effective in detecting the communication difficulties caused by SHFHL.

## DISCUSSION

Speech audiometry testing is generally regarded as clinically more acceptable than pure-tone audiometry for identifying individuals with poor auditory integrity. The SIS testing has been used in every phase of audiology and the diagnostic value of identifying and differentially diagnosing auditory disorders have been well documented [10]. With reference to Telugu, Kumar and Mohanty [19] developed four word lists known as conventional word lists (CWLs) for assessing speech identification performance of adults. It is expected that these CWLs would not be sensitive in identifying the true nature of communication difficulties caused by SHFHL. The present study developed two HFWLs for assessing individuals with SHFHL. While the physiological functioning of an individuals' auditory system is undoubtedly a major determinant of his or her hearing status, the linguistic and cultural differences should not be disregarded as they can affect every stage of audiological assessment. There is a well-established fact that the reliability and validity of speech identification or recognition testing can be influenced by factors such as word familiarity, words in common use and type of stimulus.

Telugu is spoken in Andhra Pradesh and Telangana, southern states of India, and official language of both the states. Although, the mother tongue of majority of people of two states is Telugu, some of the frequently occurring words in one region may not be familiar to people belonging to other regions due to dialectal variations [19]. Therefore, the differences in the frequency of occurrence of a test word in two dialects might affect the word identification performance by representatives of the two different dialects. The intelligibility of speech stimuli increases when the subject's level of familiarity with the stimulus items is greater [20]. Since 'word familiarity' show greater effect on speech recognition performance, we have carried out familiarity assessment on native speakers of Telugu belonging to different regions (Coastal Andhra and Rayalaseema of Andhra Pradesh, and Telangana) in order to ensure that the test words are known to native speakers of Telugu. The next step after familiarity assessment was selection of 'words in common use' by native speakers of Telugu belonging to different regions. Therefore, the words rated as 'most familiar' were listed for each group of native speakers of Telugu separately and these words were further assessed for homogeneity across the groups in order to ensure that selected words were known to and were commonly used by them. These words were

further subjected to content validity in order to review how essential these words can attribute to the test measures (discussed in detail in the method). This pool of words served as foundation for developing high frequency speech identification test in Telugu.

Another important consideration in the development of word lists for assessing speech identification performance is the type of stimuli used. Monosyllabic words with consonant-vowel-consonant (CVC) structure are generally used and widely accepted in developing either CWLs or HFWLs for assessing speech identification performance. This is mainly due to the fact that these are minimum meaningful units, non-redundant and common in languages like English and most of the Indian languages. But some Indian languages are vowel ending (e.g. Kannada, Telugu) and the occurrence of monosyllabic words is minimal in such languages. Hence, it is difficult to construct monosyllabic word lists in such languages because of the scarcity of occurrence of monosyllabic words. Considering this Kumar and Mohanty [19] developed CWLs in Telugu by considering disyllabic words having CVCV structure. Hence, we have also developed two HFWLs by considering disyllabic words having CVCV structure in the present study.

The phonemes upon which the word lists are constructed is an important consideration while developing HFWLs. The word lists composed with voiceless phonemes would be ideal in identifying the perceptual difficulties of individuals with SHFHL. In addition, the words with vowels /i/ and /e/ are preferred as their second and third formant frequencies (F2 and F3) are higher than that of the other vowels [17]. Telugu consists of a total of nine voiceless consonants such as /k, c, ṭ, t, p, s, ś, ṣ, h/. We have developed a total of two word lists constructed with these voiceless consonants. The words in each word list are in CVCV structure except the word /sañci/ 'bag' which has CVCCV structure (included in list 2). Each word list consists of 25 words composed with 84% of voiceless consonants. It was also ensured that each word list has equal distribution of these voiceless consonants. Although /i/ and /e/ vowels are preferred, it was observed that there is limited number of words with these vowels in combination with voiceless consonants. Hence we have included other vowels also in the word lists. However, we have carried out long-term average speech spectrum analysis of words of each list in order to ensure that the peak spectral energy of each word was above 1000 Hz.

Any measurement used to assess one's behavioural performance should be subjected to thorough standards with regard to its development to ensure that the measure accurately reflects the behaviour of interest. Reliability is a psychometric principle that plays an important role in the development of any speech identification test. Reliability refers to the extent to which measurements are repeatable by the same individual using the same measures of a particular attribute, by the same individual using different measures of the attribute, or by different people using the same measure of the attribute without the interference of error. There are four different methods commonly used to determine the reliability of speech recognition tests, including test-retest reliability, inter-list equivalence, split-half method and inter-item consistency reliability [21].

In the present study, the equivalence analysis of two word lists was carried out. The equivalence analysis of word lists was carried out in order to ensure that the two word lists must be equally difficult so that the subjects' speech identification performance obtained on one word list is similar to the performance of the same group of subjects on other word list, and on the other hand, to ensure that the subjects of different groups obtain similar speech identification performance on same word list. It was found that there was no statistically significant difference ($p>0.05$) in speech identification performance between two word lists for each group and no significant difference ($p>0.05$) between three groups for each word list. Hence, the two HFWLs were found to equally difficult and reliable materials in assessing speech identification performance.

The extent to which a test instrument appears to measure what it is supposed to measure constitutes validity. There are three categories of methods commonly used to determine the validity of speech identification tests, including construct validity, criterion related validity and content validity [21]. In the present study criterion related validity was carried out. The normal hearing subjects in the present study obtained groups' mean SISs of 99.68% and 99.60% for two word lists (i.e. HFWL-1 and HFWL-2) respectively which are falling within the normal range (i.e. 90-100%) of SIS [10]. Similar findings were reported on normal hearing subjects for CWLs in Telugu [19]. The subjects in the FFHL-Group obtained similar SIS for CWLs and HFWLs in the present study suggesting that the HFWLs are found to be equally difficult and can be considered as alternative forms to CWLS for assessing

**Appendix: High Frequency Word Lists**

| List 1 | | List 2 | | List 1 (Random) | | List 2 (Random) | |
|---|---|---|---|---|---|---|---|
| కోతి | kōti | తోక | tōka | పాత | pāta | పాట | pāṭa |
| చేదు | cēdu | గుహ | guha | చాప | cāpa | సైగ | saiga |
| తేపు | tēpu | చూపు | cūpu | షోకు | ṣōku | చేశా | cēśā |
| పేగు | pēgu | కథ | katha | దోశ | dōśa | చేప | cēpa |
| టోపీ | ṭōpī | గాటు | gāṭu | గేటు | gēṭu | సీటు | sīṭu |
| పాచి | pāci | పాట | pāṭa | పూస | pūsa | చీమ | cīma |
| సాకు | sāku | చీటి | cīṭi | చూశా | cūśā | సూది | sūdi |
| కాకి | kāki | కేక | kēka | పోటీ | pōṭī | తాట | tāṭa |
| దోశ | dōśa | పీట | pīṭa | చీర | cīra | షాపు | ṣāpu |
| పోటు | pōṭu | సైగ | saiga | తీగ | tīga | పీక | pīka |
| చాప | cāpa | పూత | pūta | తోట | tōṭa | సంచి | sañci |
| షోకు | ṣōku | చేప | cēpa | పాచి | pāci | కేక | kēka |
| పూస | pūsa | కసి | kasi | సెగ | sega | గుహ | guha |
| గేటు | gēṭu | పొగ | poga | కోతి | kōti | చూపు | cūpu |
| పోటీ | pōṭī | చేశా | cēśā | చాట | cāṭa | గాటు | gāṭu |
| కోడి | kōḍi | కోటు | kōṭu | కాకి | kāki | తోక | tōka |
| సీసా | sīsā | షాపు | ṣāpu | పగ | paga | చీటి | cīṭi |
| చాట | cāṭa | గీత | gīta | టోపీ | ṭōpī | కథ | katha |
| పగ | paga | సూది | sūdi | పేగు | pēgu | పీట | pīṭa |
| తోట | tōṭa | సీటు | sīṭu | సాకు | sāku | కసి | kasi |
| సెగ | sega | చీమ | cīma | తేపు | tēpu | పూత | pūta |
| చీర | cīra | తాట | tāṭa | చేదు | cēdu | పొగ | poga |
| పాత | pāta | సంచి | sañci | పోటు | pōṭu | చారు | cāru |
| చూశా | cūśā | పీక | pīka | సీసా | sīsā | కోటు | kōṭu |
| తీగ | tīga | చారు | cāru | కోడి | kōḍi | గీత | gīta |

speech identification performance of individuals with FFHL. However, the subjects in the SHFHL-Group obtained significantly higher SIS for CWLs as compared to HFWLs in the present study. Hence it can be inferred that the CWLs would overestimatethe performance of individuals with SHFHL and not indicate the true nature of communication difficulties caused by SHFHL. This could be attributed to the reason that individuals with SHFHL would have difficulty mainly in the perception of speech sounds having energy concentration in the higher frequency regions. The CWLs developed by Kumar and Mohanty

[19] were constructed with 56% voiced consonants and only 44% with voiceless consonants. Hence, the words constructed with voiced consonants such as /nēnu/, /lēdu/, /mīru/, /lōya/, /wāna/ etc. in list 1, /nīḍa/, /rāyi/, /dōma/, /dāri/, /gāli/ etc. in list 2, /nōru/, /wāḍu/, /railu/, /mūga/, /wūru/ etc. in list 3, and /bāwa/, /nādi/, /lāri/, /wēḍi/, /nūne/ etc. in list 4 might have provided redundant information when administered on individuals with SHFHL because of near normal or better perception of low frequency speech information.

On the other hand, the subjects in SHFHL-Group obtained significantly lower SIS for HFWLs as compared to CWLs. This could be attributed to the reasons that unlike individuals with FFHL, individuals with SHFHL would face more difficulties in the perception of voiceless consonants as they have energy concentration in the high frequency regions and contain so little energy as compared to voiced consonants. The two HFWLs developed in the present study were constructed with 84% of voiceless consonants.Each list consists of 17 words composed only with voiceless consonants, i.e. in voiceless consonant–vowel–voiceless consonant structure, e.g. /kōti/, /cūpu/, /ṭōpi/, /cāpa/, /pāta/, /sāku/, /cāṭa/ etc. Although remaining words are not completely composed with voiceless consonants, they are composed with at least with one voiceless consonant, i.e. either in voiced consonant–vowel–voiceless consonant structure, e.g. /gēṭu/, /dōśa/, /guha/, /gĪta/ etc. or in voiceless consonant–vowel–voiced consonant structure, e.g. /kōḍi/, /sūdi/, /cēdu/, /cĪma/ etc. This could be reason that individuals with SHFHL obtained significantly lower speech identification performance with HFWLs as compared to CWLs. Thus it can be concluded that the two HFWLs developed in the present study can be considered reliable and valid materials in assessing speech identification performance of individuals with SHFHL.

## CONCLUSION

Speech identification assessment ideally should reflect the true communication difficulties created by hearing loss. The effect of hearing loss on communication abilities of an individual depends on type, degree and configuration of hearing loss. The most challenging audiogram configurations audiologist faces are SHFHL. Individuals with SHFHL face difficulty mainly in perceiving speech sounds having energy concentration in the high frequency region. Hence, there is a need to develop speech identification test that is effective in identifying true communication difficulties caused by SHFHL. The present study developed two HFWLs for assessing individuals with SHFHL. These HFWLs were found to be reliable and valid materials for describing the extent of communication problems created by SHFHL as compared CWLs. The developed HFWLs can be used in the selection, fitting and verification of appropriate amplification devices for individuals with SHFHL. These word lists will be particularly useful in evaluating the need and benefits of frequency lowering hearing aids utilizing strategies such as frequency compression, frequency transposition, and frequency translation strategies. The same materials can be used in providing auditory training of high frequency words for individuals with hearing impairment.

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