Journal of Rehabilitation Sciences and Research

Journal Home Page: jrsr.sums.ac.ir

Review Article

A Literature Review of Voice Indices Available for Voice Assessment

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ARTICLE INFO

Article History:
Received: 21/10/2021
Revised: 13/02/2022
Accepted: 13/02/2022

Keywords:
Voice
Voice disorders
Dysphonia
Voice quality
Acoustics

Please cite this article as:
Saeedi S, Aghajanzadeh M, Khatoonabadi AR. A Literature Review of Voice Indices Available for VoiceAssessment.JRSR.2022;9(4):151-155.

ABSTRACT

Background: Recent years have seen the development of voice indices for multi-parametric objective voice evaluation. The current study aims to review these indices and examine their efficiency through the literature.
Methods: The study design is a literature review. The five databases of 'PubMed', 'Scopus', 'Google Scholar', 'Science Direct', and 'Web of Science' were searched using the keywords 'voice index', 'acoustic', 'voice assessment', and 'acoustic analysis'. Attempts were made to include only the acoustic indices that have been validated and are fairly user-friendly.
Results: Five voice indices were found that met the inclusion criteria: Dysphonia Severity Index (DSI), Acoustic Voice Quality Index (AVQI), Cepstral Spectral Index of Dysphonia (CSID), The Acoustic Breathiness Index (ABI), and Acoustic Psychometric Severity Index of Dysphonia (APSID).
Conclusions: The results suggest using AVQI, ABI, DSI, and CSID in the evaluation and treatment of voice disorders. Of course, it is recommend to examine the efficacy of these indices in more languages and also developing new indices by considering more aspects of voice.

Background

The evaluation of voice is the basis of a perfect treatment process [1]. This statement reminds us of how precisely the assessment process should be organized. The assessment process usually comprises sections such as visual laryngoscopy, auditory-perceptual evaluation, aerodynamic evaluation, acoustic analysis, and vocal self-assessment [2].

Among the different parts of the voice assessment, auditory-perceptual evaluation is deemed the gold standard; however, this evaluation is at risk for some biases, including 1) the clinician's level of experience in the field of voice disorders, 2) the severity of dysphonia, 3) kind of auditory-perceptual rating scale, and 3) the type of speech task [3-14]. These problems of auditory-perceptual evaluation have motivated researchers and clinicians to use those instrumental measurements that help them consider voice problems quantitatively [15].

Acoustic measurements are objective measurements that have received a lot of attention [16]. Roy et al. showed that most voice assessment studies have been conducted in the area of acoustics [17]. With technological advances and the availability of relevant tools, the clinical use of acoustic analysis is increasing [1]. The provision of objective data, noninvasiveness, low cost, and ease of application of acoustic measurements compared with other parts of the evaluation are among the benefits of this technique [16, 18]. Acoustic analysis leads to specific quantitative data which can guide us in: 1) characterizing the severity of dysphonia, 2) comparing a patient's voice before and after treatment, and 3) interactions between the members of the voice care team as regards the patient's voice condition [15].

A substantial number of studies have been conducted to realize the relationship of these parameters with auditory-

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perceptual scales so as to develop a better understanding of the power of acoustic measurements. For example, Maryn et al. (2009) showed that just a few univariate acoustic parameters had moderate to high correlation with overall voice quality [19]. To solve the validity issue of univariate acoustic parameters and considering the multidimensional nature of the human voice, the combinational use of parameters was presented by a number of researchers [20-23].

Some voice indices were developed by researchers in earlier years. These indices are statistical models that integrate variant parameters such as acoustic and aerodynamic factors and make a specific combinational number. These indices provide a numeric range to compare the examinee's number versus normal values. With these values, it is possible to track a patient's progress before and after treatment and to evaluate a patient's condition at the first session. To reach a better understanding of a patient's voice disorder, these indices provide a brighter image relative to a solitary parameter [18].

It is noteworthy that the application of a multi-parametric fashion is also widespread in other areas of medical sciences, and it is not limited to the voice disorders area only [21]. The body mass index (BMI) is one of the well-known indices used in nutritional science to judge obesity and weight loss. Instead of relying on one's weight per se to diagnose, BMI uses the parameter of height in addition to weight. With a quite simple calculation (body mass divided by the square of the body height), it is feasible to match one's BMI value with different numerical ranges and then categorize him/her into one of these groups: underweight, normal weight, overweight, or obese [24, 25].

Throughout the authors' research, no review article was found that gave brief organized information about acoustic indices to clinicians and scholars, and there is a clear informational gap in this area. Therefore, the current study aimed to present a brief review of clinical acoustic indices for dysphonic patients and evidence of their validation and validity in different languages.

Methods

For this literature review, five scientific electronic databases, namely 'PubMed', 'Scopus', 'Google Scholar', 'Science Direct', and 'Web of Science', were selected based on their relevancy to the medical areas. These databases were searched with keywords including: 'voice index', 'acoustic', 'voice assessment', and 'acoustic analysis.' To avoid missing papers, a manual search was also done, and some of the referred studies in selected articles were also chosen. The inclusion criteria comprised articles with the subject of voice acoustic indices and other associated evidence of the efficiency of these indices in different languages. Attempts were made to select only indices that are able to be administrated clinically. Some acoustic indices that are difficult for clinicians to perform or models with unclear calculation methods were removed. The time period of the search was limited to between the years 2000 and 2021. Ultimately, 21 articles were selected for this study based on the authors' proficiency in English.

Article selection began with title investigation. Initially, studies with irrelevant titles and duplicated items were discarded. Next, the abstract of the remaining articles were read carefully. Each meta-analysis review, systematic review, case-control, cross-sectional, and cohort study in which the primary focus was developing an acoustic index or examining the efficacy of an acoustic index was included. No participants' language or age range limitation was applied. Because editorial notes, letters, and short surveys are considered as the lowest level of scientific evidence, they were excluded from the current study. Finally, the full text of each article was read comprehensively and analyzed descriptively. Any disagreement between the authors regarding selected articles was settled through discussion and consent. No statistical operation was conducted because of the traditional narrative review design.

Results

Dysphonia Severity Index (DSI)

Wuyts et al. developed the DSI to assess voice quality. DSI consists of acoustic, aerodynamic, and voice range components. In this multidimensional index, four parameters are weighted: highest frequency (F0-High in Hz), lowest intensity (I-Low in dB), maximum phonation time (MPT in seconds), and jitter (%), and calculated as: $DSI=0.13\times MPT+0.0053\times F0\text{–}High–0.26\times I\text{-}Low–1.18\times Jitter\ (\%)+12.4$. The range of DSI figures is between–5 and+5; a more negative score means a more dysphonic voice, and a more positive score indicates a healthier voice. According to the authors of the referenced study, DSI can be used reliably in a voice clinics in addition to other standard assessment tools [21].

One systematic review and meta-analysis research was found that had gathered DSI values in previous published articles. Sobol and Sielska-Badurek did research on finding normative DSI scores through the relevant literature. Their results revealed that the cut-off DSI score in healthy subjects was 3.05. They further pointed out that the DSI confidence level was in the range of 2.13 to 3.98, a little lower relative to the previous range [26].

Acoustic Voice Quality Index (AVQI)

Maryn et al. (2010) developed a multi-parametric voice index named AVQI to assess the overall severity of voice disorders. The authors tried to use vowel context and connected speech simultaneously to attain a better picture of vocal condition despite the traditional use of only vowels. Their attempts led to an acoustic model with six variables: the AVQI equation is: $AVQI=(3.295–0.111\times CPPs–0.073\times HNR–0.213\times shimmer\ local+2.789\times shimmer\ local\ dB–0.032\times slope+0.077\times tilt)\times 2.571$. AVQI figures range between–0.39 and 3.50; higher scores indicate a more severe voice disorder. The results showed that AVQI has satisfactory precision in determining the dysphonia severity level [15].

Maryn et al. attempted to investigate the power of AVQI in four different languages (English, Dutch, German, and French); their results were indicative of the validity and accuracy of this index in measuring voice disorder severity through these various languages [27].

Several other scholars have attempted to validate AVQI in different languages. To date, this index had been developed in Japanese, Lithuanian, Spanish, French, Brazilian Portuguese, Korean, Kannada, Finnish, German, and Turkish; the AVQI was identified as a valid tool in all of these languages [28-37].

Cepstral Spectral Index of Dysphonia (CSID)

Predicting the level of dysphonia severity in Analysis of Dysphonia in Speech and Voice (ADSV), an acoustic analysis software, is called CSID. CSID is a cepstral/spectral-based analysis based on the analyses of Awan et al. to assess dysphonia severity [38-40].

Peterson et al. tried to examine the efficacy of CSID in tracking voice disorder severity before and after treatment. Their results suggest that CSID could be utilized in clinical areas to follow the patient's voice condition through the treatment period, because it was shown that CSID had a significant correlation with perceptual assessments [41].

Awan et al. tried to evidence the power of CSID in screening dysphonia. Considering perceptual judgment, laryngoscopy, and Voice Handicap Index (VHI) score, the researchers stated that CSID could discriminate between normal and dysphonic voice; however, CSID had the most powerful correlation with perceptual judgment. Their results showed that clinicians could utilize this index as a beneficial screening tool with approximately 24.3 as the cut-off to decide whether further evaluation is required [42].

No research was found to have examined CSID validity and reliability in different languages.

Acoustic Breathiness Index (ABI)

Latoszek et al. developed a voice index as a way to quantify the breathiness characteristic of a dysphonic voice. The ABI equation is: ABI=(5.0447730915–[0.172×CPPs]–[0.193×Jit]–[1.283×GNEmax–4500 Hz]–[0.396×Hfno–6000 Hz]+[0.01×HNR–D]+[0.017×H1–H2]+[1.473×Shim–dB]–[0.088×Shim]–[68.295×PSD])×2.9257400394. The abbreviations in the equation are as follows: Jit=Jitter, GNEmax=maximum glottal-to-noise-excitation, Hfno=high-frequency noise, HNR-D=harmonics-to-noise ratio according to Dejonckere and Lebacq [43], H1–H2=differences between the amplitudes of the first and second harmonics in the spectrum, Shim=shimmer, PSD=period standard deviation. ABI amounts range from 0 to 10. There is a direct relationship between these figures and the perceived severity of breathiness; the higher the ABI amount is, the more severe the breathiness is. Results showed that ABI had a significant correlation with the auditory perceptual assessment of breathiness and is a valid index for diagnosing breathiness in clinical practice [44].

A meta-analysis performed by Latoszek et al. with the aim of examining the efficacy of ABI in different languages (Dutch, German, Spanish, Brazilian Portuguese, Korean, and Japanese) showed that ABI is a valid tool to objectify breathiness and differentiate between dysphonic patients with breathiness and normal people [45].

Acoustic Psychometric Severity Index of Dysphonia (APSID)

Lee et al. developed a new index named APSID with the aim of screening voice disorders. This index boasts the innovation of including demographic and psychometric as well as acoustic parameters. The APSID equation is: $APSID=84.984–(7.159×CPP_s)+(2.104×severity)+(5.724×CPP_v)–(2.054×CPP_v)$ -(5.174×gender). In this equation, $_s$ means 'in sentence production task,' $_v$ means 'vowel production task,' and means 'standard deviation.' Moreover, for men, 0 and for women, 1 should be inserted. Severity is a self-perceived score in the Korean version of the Voice Activity and Participation Profile (K-VAPP). The study results revealed that APSID could be considered as a screening tool to distinguish dysphonia versus normal voice. However, as the authors recommended, more research should be done to identify other benefits of this index, such as its potential to measure the status of voice in the treatment period [46]. According to the search results, APSID has not been investigated in other studies (Tables 1 and 2).

Table 1: General characteristics of the development studies of indices

Index	Authors and Study Year	Country	Aim of the index	No. of Participants	Participant age range	Speech Task
DSI	Wuyts et al. (2000) [21]	Belgium	Voice quality assessment	319 dysphonic 68 normal	18–80	Sustaining vowel
AVQI	Maryn et al. (2010) [15]	Belgium/USA	Assessment of the overall severity of voice disorders	229 dysphonic 22 normal	8 to 85 Mean: 38.9 (±19.5).	Sustaining vowel and reading
CSID	Peterson et al. (2013) [41]	USA	Dysphonia severity assessment	112 dysphonic	N/A	Sustaining vowel/ reading
	Awan et al. (2016) [41]	USA	Dysphonia severity assessment	258 dysphonic 74 normal	Mean: 51.94 (±16.22)	Sustaining vowel/ reading
ABI	Latoszek et al. (2017) [44, 45]	Belgium/The Netherlands	Quantifying breathiness	970 dysphonic 88 normal	Patients: 42.40±21.13 Normal (women): 35.95±16.18 Normal (men): 34.06±18.50	Reading/ sustaining vowel
APSID	Lee et al. (2019) [46]	Republic of Korea	Screening of voice disorders	150 dysphonic 50 normal	Patients: 45.15±15.15 Normal: 44.78±13.70	Sustaining vowel/ Reading

DSI, Dysphonia Severity Index; AVQI, Acoustic Voice Quality Index; CSID, Cepstral Spectral Index of Dysphonia; ABI, Acoustic Breathiness Index; APSID, Acoustic Psychometric Severity Index of Dysphonia; N/A, not applicable

Table 2: Psychometric characteristics of indices

Index	Score range	Cut-off	Sensitivity	Specificity
DSI	-5 to+5	3.05 (DSI confidence level between 2.13 to 3.98)	N/A	N/A
AVQI	–0.39 to 3.50	2.36	91%	59%
CSID	N/A	24.27	79.41%	79.01%
ABI	0 to 10	3.44	82.4%	92.9%
APSID	N/A	22.25	82.12%	94%

DSI, Dysphonia Severity Index; AVQI, Acoustic Voice Quality Index; CSID, Cepstral Spectral Index of Dysphonia; ABI, Acoustic Breathiness Index; APSID, Acoustic Psychometric Severity Index of Dysphonia; N/A, not applicable

Discussion

The evaluation of any voice disorder is very important to both the voice care team and the patient. Any mistake in this process might have considerable consequences for the patient such as selecting an inappropriate and risky intervention or underestimating the severity of dysphonia.

There are a lot of clinical tools to assess the voice, but tools that give the clinician quantitative results can provide an obvious understanding of the patient's condition compared with qualitative data, such as outcomes of auditory-perceptual evaluation or imaging studies. Although the golden standard of voice disorder diagnosis is auditory-perceptual examinations, the proficiency of this method depends on clinical experience, and newcomer clinicians may misdiagnose [42].

One quantitative assessment method is the use of acoustic analysis and relevant voice indices. In the last decade, several researchers have tried to develop and introduce voice indices for screening or evaluating voice disorders. These tools merge a range of parameters and make a formula. By using some instead of only one parameter, the possibility of error will be significantly reduced [18]. These indices have quantitative results that help the clinician complete the assessment process. Quantitative tools are able to help clinicians compare their patient's voice condition with the cut-off point and consider the normal and disordered numerical ranges. With this information, voice care team members can complete their auditory-perceptual evaluations or imaging studies and make a better decision. Another benefit of voice indices is that they allow the tracking of changes in a patient's values before and after treatment. By comparing these two numbers, the voice care team may determine whether the patient has progressed through treatment and the possibility of discharging the case or using another treatment.

Five voice indices have been investigated in this review article. The author's research showed that these indices do not have an even distribution of confirming evidence. Through these tools, the results indicated that AVQI and ABI have reliable evidence; they have shown robust results in different languages. However, the validity and reliability of the DSI have not been explored directly in various languages. Nonetheless, this model has been used in many studies as a parameter for tracking the treatment effect or in evaluation studies universally. CSID has some levels of evidence; compared with DSI, however, it requires more attention in future studies. Although APSID provides a combination of acoustic, demographic, and psychometric data, which is very novel, it has the least associated evidence, possibly because of its being new.

The author strongly recommends that researchers in this field collect more data about the efficacy of the clinical use of APSID in different languages in addition to other indices. It is also recommended to develop other novel and creative indices that combine variant parameters such as APSID. It seems that synthesizing other parameters is required to examine the voice holistically and to decrease errors during evaluation and diagnosis.

Conclusion

The outcomes of this investigation suggest that AVQI, ABI, DSI, and CSID be used by voice care teams, including speech and language pathologists (SLPs) and ear, nose, and throat specialists (ENTs), to complete their assessments and give the patient a more appropriate treatment if needed.

Conflict of Interest: None declared.

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