Literature Review

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Measurements of the effect of interventions on heathly voices: a scope review

Medidas de efeito das intervenções em vozes saudáveis: uma revisão de escopo

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ABSTRACT

Purpose: to map the vocal assessment measures used to verify the effect of the intervention in vocally healthy individuals. **Research strategy:** This is a scope review based on the research question: What vocal assessment measures are used to verify the effect of the intervention in vocally healthy individuals? The search was carried out electronically in MEDLINE (PubMed), LILACS (BVS), Scopus (Elsevier), Web of Science (Clarivate), Embase and Cochrane databases. **Selection criteria:** The selection of studies was based on reading the titles, abstracts, keywords and full texts, applying the eligibility criteria. Data related to the publication's bibliographic information, sample and intervention characteristics, the effects of the intervention on self-assessment, auditory-perceptual, acoustic, aerodynamic, electroglottographic measures, laryngeal examination results, among others, were extracted. The data were summarized and presented in a quantitative and descriptive way. **Results:** 97 articles were selected, among the 979 studies mapped in this review. Acoustic analysis was the most used measure (n=70, 72.3%) to verify the effects of vocal training in the selected studies, followed by electroglottography (n= 55, 56.7%), self-assessment (n= 38, 39 .2%), aerodynamics (n= 33, 34.0%), auditory-perceptual judgment (n= 22, 22.7%) and laryngeal examination (n= 16, 16.5%). **Conclusion:** Acoustic analysis is the measure used in most studies to verify the effect of the intervention in vocally healthy individuals.

Keywords: Voice; Voice quality; Voice training; Results study; Review; Healthy volunteers

RESUMO

Objetivo: mapear as medidas de avaliação vocal utilizadas para verificar o efeito da intervenção em indivíduos vocalmente saudáveis. **Estratégia de pesquisa:** trata-se de uma revisão de escopo baseada na questão de pesquisa: "Quais as medidas de avaliação vocal utilizadas para verificar o efeito da intervenção em indivíduos vocalmente saudáveis?" A busca foi realizada de forma eletrônica nas bases de dados MEDLINE (PubMed), LILACS (BVS), Scopus (Elsevier), Web of Science (Clarivate), Embase e Cochrane. **Critérios de seleção**: a seleção dos estudos foi baseada na leitura dos títulos, resumos, palavras-chave e textos completos, aplicando-se os critérios de elegibilidade. Foram extraídos os dados relacionados às informações bibliográficas da publicação, características da amostra e da intervenção, os efeitos da intervenção nas medidas de autoavaliação, perceptivo-auditivas, acústicas, aerodinâmicas, eletroglotográficas, resultado do exame laríngeo, entre outros. Os dados foram resumidos e apresentados de forma quantitativa e descritiva. **Resultados:** foram selecionados 97 artigos, entre os 979 estudos mapeados nesta revisão. A análise acústica foi a medida mais utilizada (n=70, 72,3%) para verificar os efeitos do treinamento vocal nos estudos selecionados, seguida pela eletroglotografia (n= 55, 56,7%), autoavaliação (n= 38, 39,2%), aerodinâmica (n= 33, 34,0%), julgamento perceptivo-auditivo (n= 22, 22,7%) e exame laríngeo (n= 16, 16,5%). **Conclusão:** a análise acústica é a medida utilizada na maioria dos estudos para verificar o efeito da intervenção em indivíduos vocalmente saudáveis.

Palavras-chave: Voz; Qualidade da voz; Treinamento da voz; Estudo dos resultados; Estudos de revisão; Voluntários saudáveis

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INTRODUCTION

Voice assessment should be preferably multidimensional, including a detailed survey of the patient's medical history to identify their complaints, risk factors, and symptoms; auditory-perceptual evaluation (APE) to characterize the quality of the voice and parameters such as pitch, loudness, resonance, articulation, and so forth; acoustic analysis of the voice to characterize the voice signal; an endoscopic laryngeal examination to analyze the structure (telelaryngoscopy and nasopharyngolaryngoscopy) and vibration (videostroboscopy) of the larynx; aerodynamic assessment to obtain data on airflow control for phonation[1]; and self-assessment, which is important as it considers the patient's perception of their voice and its problem[2]. Other methods can be also used to verify voice production or the structures (cavities and muscles) involved in phonation, such as electroglottography, surface electromyography, sensors fixed on the neck, computed tomography, magnetic resonance, and so on.

In general, voice assessment aims to identify, characterize, and quantify voice problems, improve the person's voice, and monitor the effectiveness of the treatment or training provided to the patient[3]. Researchers in the areas have generally and more intensely focused on understanding the process of diagnosing voice problems. However, there is a lack of studies on the parameters that must be used to verify the effectiveness of voice training given to vocally healthy individuals.

There is a worldwide consensus on investing more intensely in promoting health and increasing the quality of life in the population[4]. In speech-language-hearing (SLH) therapy, the recent planning of the American Speech-Language-Hearing Association (ASHA) recommends that the profession increase its emphasis on preventive and occupational medicine by 2030 to improve the quality of life in healthy populations, addressing communication health determinants and the healthy lifestyle related to human communication[5]. As for the field of voice, specifically, people with no voice complaints related to dysphonia seek SLH care to improve their voice and communication and improve their social and occupational participation[6,7]. Great heterogeneity was recently observed in the design of studies aiming to verify the characteristics and effects of SLH intervention in vocally healthy individuals[6]. On the other hand, there is no consensus on the most relevant indicators or outcomes to approach when assessing and monitoring the effects of SLH intervention in vocally healthy populations[6]. Hence, given the increasing demand for vocally healthy individuals in SLH practice, there is an important gap in the scientific literature concerning relevant effect measures or outcomes to consider in SLH approach to this population.

Monitoring the effectiveness of intervention involves choosing tasks and procedures capable of measuring auditory-perceptual, acoustic, physiological, and self-perceptible changes in voice production[1-3,6]. The literature has indicated self-assessment measures, APE, acoustic analysis, laryngeal videostroboscopy, and aerodynamic assessment, especially to verify the effectiveness of the intervention in dysphonic patients[1]. In the clinical context, some publications recommend the clinical and instrumental assessment of the voice[1].

However, there is a lack of information on recommended tasks and procedures to monitor[8] the effectiveness of the SLH approach in training or habilitating the voice of vocally healthy individuals, whether occupational voice users or from the general population. Voice training normally aims to improve the efficiency of voice production for specific demands in either speaking or singing[9]. Differences in these individuals' complaints and expectations, when they seek to improve their healthy voices, justify the selection or development of different monitoring strategies.

Thus, the research question that motivated this research was defined as, "What voice assessment measures are used to verify the effects of interventions in vocally healthy individuals?". This review may help develop further research and make specific recommendations on procedures to assess and monitor the effects of intervention in vocally healthy individuals.

OBJECTIVE

This review aimed to map voice assessment measures used to verify the effects of intervention in vocally healthy individuals.

RESEARCH STRATEGY

This scoping review was designed according to the guidelines of the Joanna Briggs Institute (JBI) for scoping reviews[10] and described according to the PRISMA Extension for Scoping Reviews (PRISMA-ScR).

The PCC acronym (P – population, C – concept, and C – context) was used to design the study, as follows: P – vocally healthy individuals; C – voice assessment measures – belonging to multidimensional voice assessment; and C – direct, indirect, or both interventions.

Search

The search was conducted electronically in the MEDLINE (PubMed), LILACS (VHL), Scopus (Elsevier), Web of Science (Clarivate), EMBASE, and Cochrane databases. The search strategies were developed based on uniterms indexed in the Medical Subject Headings (MeSH), Health Sciences Descriptors (DeCS), and free terms related to the PCC. A previous search was made for studies that might be included to confirm whether the present research would not be an empty review – which verified primary studies on the topic in the literature. This search was conducted in the MEDLINE database. In the mapping process, the initial screening used relevant terms in the articles' titles, abstracts, and keywords to improve the search strategy and devise a final search plan for the other databases. Then, the last search strategy was developed specifically for each database. Table 1 presents the final search strategy used for the databases.

Two independent reviewers searched and selected the studies and extracted their data, and a third reviewer solved divergences. The searches were conducted in June 2022. This study did not search for studies in the grey literature.

SELECTION CRITERIA

The following eligibility criteria were used for the selection: studies in vocally healthy individuals (with no voice complaints, no voice quality deviations, and no structural or functional laryngeal

Table 1. Search strategies for the databases

Databases	Strategy	Number of mapped studies
PubMed/ MEDLINE	((“healthy volunteers”[MeSH] OR “healthy volunteers” OR “Normal Speakers” OR “normal healthy participants” OR “healthy adult” OR “healthy subject” OR “healthy subjects” OR “healthy volunteer” OR “normal humans” OR “normal subject” OR “normal subjects” OR “normal volunteer” OR “normal volunteers”) AND (“voice training”[MeSH] “voice training” OR “Speech Therapy”[MeSH] OR “Speech Therapy” OR “vocal exercise” OR “vocal hygiene” OR “voice therapy” OR “vocal therapy” OR “Voice Rehabilitation” OR “vocal rehabilitation” OR “vocal intervention” OR “vocal interventions” OR “Voice Treatment” OR “Voice Treatments” OR (“Physical Functional Performance”[Mesh] AND Voice[Mesh]) OR (“Warm-Up Exercise”[Mesh] AND Voice[Mesh]) OR (Intervention AND Voice[Mesh]) OR (Exercise AND Voice[Mesh])) AND (“self assessment”[MeSH] OR “self assessment” OR “speech acoustics”[MeSH] OR “speech acoustics” OR “laryngoscope”[MeSH] OR “laryngoscope” OR “stroboscopy”[MeSH] OR “stroboscopy” OR “voice quality”[MeSH] OR “voice quality” OR “acoustic analysis” OR “glottography” OR “voice parameter” OR “rating scales” OR “objective voice measurements” OR “auditory-perceptual evaluation of voice” OR “voice assessment” OR “aerodynamics” OR “aerodynamic” OR “Patient Reported Outcome Measures”[MeSH] OR “Patient Reported Outcome Measures” OR “patient-reported outcome” OR “outcome assessment”))	274
LILACS (VHL)	((healthy volunteers) OR (healthy volunteers) OR (Normal Speakers) OR (normal healthy participants) OR (healthy adult) OR (healthy subject) OR (healthy subjects) OR (healthy volunteer) OR (normal humans) OR (normal subject) OR (normal subjects) OR (normal volunteer) OR (normal volunteers)) AND ((voice training) OR (voice training) OR (Speech Therapy) OR (Speech Therapy) OR (vocal exercise) OR (vocal hygiene) OR (voice therapy) OR (vocal therapy) OR (Voice Rehabilitation) OR (vocal rehabilitation) OR (vocal intervention) OR (vocal interventions) OR (Voice Treatment) OR (Voice Treatments) OR (Physical Functional Performance) OR (Warm-Up Exercise) OR (Intervention) OR (Exercise) AND (Voice)) AND ((self assessment) OR (self assessment) OR (speech acoustics) OR (speech acoustics) OR (laryngoscope) OR (laryngoscope) OR (stroboscopy) OR (stroboscopy) OR (voice quality) OR (voice quality) OR (acoustic analysis) OR (glottography) OR (voice parameter) OR (rating scales) OR (objective voice measurements) OR (auditory-perceptual evaluation of voice) OR (voice assessment) OR (aerodynamics) OR (aerodynamic) OR (Patient Reported Outcome Measures) OR (Patient Reported Outcome Measures) OR (patient-reported outcome) OR (outcome assessment))	69
Scopus (Elsevier)	(TITLE-ABS-KEY (“healthy volunteers” OR “Normal Speakers” OR “normal healthy participants” OR “healthy adult” OR “healthy subject” OR “healthy subjects” OR “healthy volunteer” OR “normal humans” OR “normal subject” OR “normal subjects” OR “normal volunteer” OR “normal volunteers”) AND TITLE-ABS-KEY (“voice training” OR “Speech Therapy” OR “vocal exercise” OR “vocal hygiene” OR “voice therapy” OR “vocal therapy” OR “Voice Rehabilitation” OR “vocal rehabilitation” OR “vocal intervention” OR “vocal interventions” OR “Voice Treatment” OR “Voice Treatments”) OR TITLE-ABS-KEY (“Physical Functional Performance” OR “Warm-Up Exercise” OR intervention OR exercise AND voice) AND TITLE-ABS-KEY (“self assessment” OR “speech acoustics” OR “laryngoscope” OR “stroboscopy” OR “voice quality” OR “acoustic analysis” OR “glottography” OR “voice parameter” OR “rating scales” OR “objective voice measurements” OR “auditory-perceptual evaluation of voice” OR “voice assessment” OR “aerodynamics” OR “aerodynamic” OR “Patient Reported Outcome Measures” OR “patient-reported outcome” OR “outcome assessment”))	235
Web of Science (Clarivate)	(TS=(“healthy volunteers” OR “healthy volunteers” OR “Normal Speakers” OR “normal healthy participants” OR “healthy adult” OR “healthy subject” OR “healthy subjects” OR “healthy volunteer” OR “normal humans” OR “normal subject” OR “normal subjects” OR “normal volunteer” OR “normal volunteers”) AND TS=(“voice training” OR “voice training” OR “Speech Therapy” OR “Speech Therapy” OR “vocal exercise” OR “vocal hygiene” OR “voice therapy” OR “vocal therapy” OR “Voice Rehabilitation” OR “vocal rehabilitation” OR “vocal intervention” OR “vocal interventions” OR “Voice Treatment” OR “Voice Treatments” OR “Physical Functional Performance” AND “Voice” OR “Warm-Up Exercise” AND “Voice” OR “Intervention” AND “Voice” OR “Exercise” AND “Voice”) AND TS=(“self assessment” OR “self assessment” OR “speech acoustics” OR “speech acoustics” OR “laryngoscope” OR “laryngoscope” OR “stroboscopy” OR “stroboscopy” OR “voice quality” OR “voice quality” OR “acoustic analysis” OR “glossography” OR “voice parameter” OR “rating scales” OR “objective voice measurements” OR “auditory-perceptual evaluation of voice” OR “voice assessment” OR “aerodynamics” OR “aerodynamic” OR “Patient Reported Outcome Measures” OR “Patient Reported Outcome Measures” OR “patient-reported outcome” OR “outcome assessment”))	26
EMBASE	(‘healthy volunteers’/exp OR ‘healthy volunteers’ OR ‘normal speakers’ OR ‘normal healthy participants’ OR ‘healthy adult’/exp OR ‘healthy adult’ OR ‘healthy subject’/exp OR ‘healthy subject’ OR ‘healthy subjects’/exp OR ‘healthy subjects’ OR ‘healthy volunteer’/exp OR ‘healthy volunteer’ OR ‘normal humans’/exp OR ‘normal humans’ OR ‘normal subject’/exp OR ‘normal subject’ OR ‘normal subjects’/exp OR ‘normal subjects’ OR ‘normal volunteer’/exp OR ‘normal volunteer’ OR ‘normal volunteers’/exp OR ‘normal volunteers’) AND ((((‘voice training’/exp OR ‘voice training’ OR ‘speech therapy’/exp OR ‘speech therapy’ OR ‘vocal exercise’ OR ‘vocal hygiene’/exp OR ‘vocal hygiene’ OR ‘voice therapy’/exp OR ‘voice therapy’ OR ‘vocal therapy’ OR ‘voice rehabilitation’/exp OR ‘voice rehabilitation’ OR ‘vocal rehabilitation’/exp OR ‘vocal rehabilitation’ OR ‘vocal intervention’ OR ‘vocal interventions’ OR ‘voice treatment’ OR ‘voice treatments’ OR ‘physical functional performance’/exp OR ‘physical functional performance’) AND (‘voice’/exp OR ‘voice’) OR ‘warm-up exercise’/exp OR ‘warm-up exercise’) AND (‘voice’/exp OR ‘voice’) OR ‘intervention’/exp OR ‘intervention’) AND (‘voice’/exp OR ‘voice’) OR ‘exercise’/exp OR ‘exercise’) AND (‘voice’/exp OR ‘voice’) AND (‘self assessment’/exp OR ‘self assessment’ OR ‘speech acoustics’/exp OR ‘speech acoustics’ OR ‘laryngoscope’/exp OR ‘laryngoscope’ OR ‘stroboscopy’/exp OR ‘stroboscopy’ OR ‘voice quality’/exp OR ‘voice quality’ OR ‘acoustic analysis’/exp OR ‘acoustic analysis’ OR ‘glottography’/exp OR ‘glottography’ OR ‘voice parameter’/exp OR ‘voice parameter’ OR ‘rating scales’ OR ‘objective voice measurements’ OR ‘auditory-perceptual evaluation of voice’ OR ‘voice assessment’ OR ‘aerodynamics’/exp OR ‘aerodynamics’ OR ‘aerodynamic’/exp OR ‘aerodynamic’ OR ‘patient reported outcome measures’/exp OR ‘patient reported outcome measures’ OR ‘patient-reported outcome’/exp OR ‘patient-reported outcome’ OR ‘outcome assessment’/exp OR ‘outcome assessment’)	304
Cochrane	“healthy volunteers” OR “Normal Speakers” OR “normal healthy participants” OR “healthy adult” OR “healthy subject” OR “healthy subjects” OR “healthy volunteer” OR “normal humans” OR “normal subject” OR “normal subjects” OR “normal volunteer” OR “normal volunteers” in All Text AND “voice training” OR “Speech Therapy” OR “vocal exercise” OR “vocal hygiene” OR “voice therapy” OR “vocal therapy” OR “Voice Rehabilitation” OR “vocal rehabilitation” OR “vocal intervention” OR “vocal interventions” OR “Voice Treatment” OR “Voice Treatments” OR “Physical Functional Performance” AND “Voice” OR “Warm-Up Exercise” AND “Voice” OR “Intervention” AND “Voice” OR “Exercise” AND “Voice” in Title Abstract Keyword AND “self assessment” OR “speech acoustics” OR “laryngoscope” OR “stroboscopy” OR “voice quality” OR “acoustic analysis” OR “glottography” OR “voice parameter” OR “rating scales” OR “objective voice measurements” OR “auditory-perceptual evaluation of voice” OR “voice assessment” OR “aerodynamics” OR “aerodynamic” OR “Patient Reported Outcome Measures” OR “patient-reported outcome” OR “outcome assessment” in Title Abstract Keyword - (Word variations have been searched)	71

changes), whether or not occupational voice users, using voice assessment measures belonging to the multidimensional assessment of the voice (self-assessment; evaluation in direct, indirect or both interventions; with an experimental, quasi-experimental, or before-and-after design). The review excluded: abstracts of conference proceedings, studies without voice interventions, studies in dysphonic voices, and studies in different age ranges without distinguishing the intervention results.

The studies were selected in two stages: the first process encompassed reading the titles, abstracts, and keywords of articles selected for inclusion; the second process was the full-text reading to apply exclusion criteria. These stages took place between June and August 2022.

DATA ANALYSIS

Extracted data included specific PCC details with the main significant findings of the investigated articles regarding the measures used to verify the effects of voice intervention in vocally healthy individuals. Hence, the following information was extracted: title, author, year of publication, type of research, characteristics of the sample, characteristics of the intervention, and intervention results in self-assessment, APE, acoustic, laryngeal examination, aerodynamic, and other measures. The results were collected and tabulated in a previously developed Excel spreadsheet.

Extracted data were organized as follows:

a) Information on the publication (database, title, author, and year).

b) General information on the type of research (experimental, quasi-experimental, and before-and-after). The review defined experimental studies as those that had a control group, sampling, and random allocation of participants and that manipulated a variable to verify the cause-and-effect relationship[11]. Quasi-experimental studies were those that did not randomly allocate participants to groups[11]. Before-and-after studies were those that did not control the variables with a potential influence on the outcome or randomly allocate their participants[12].

c) characteristics of the sample (sample size, number of men and women, mean age, and occupational voice users).

d) Characteristics of the interventions (summary of the intervention, type of intervention, total time of the intervention, number of sessions, frequency of sessions, and moment when the effects of the intervention were assessed). Regarding types, interventions were categorized as direct, indirect, or a combination of both. This research considered direct interventions those in which the clinical procedure changed the vocal behavior through a motor performance associated with vocal/respiratory/resonance/articulatory function, somatosensory feedback, and auditory feedback[12]. Indirect interventions were those in which the clinical procedure involved vocal guidance and advice to change cognitive, behavioral, emotional, and physical aspects associated with voice production[12]. Lastly, combined direct and indirect interventions involved the use of both types of procedures to improve or optimize voice production and behavior[12]. The moment of the assessment of the intervention effects was classified as immediate (when the effects were assessed at the end of a session in which there had been intervention) or follow-up (when the effects were assessed in a specific session in which there had been no intervention).

e) Assessment methods used (self-assessment, APE, acoustic analysis, laryngeal examination, aerodynamic assessment, and so forth).

f) Measures used in each assessment method.

g) Effects of the intervention on the investigated measures.

RESULTS

Altogether, 979 studies were found in the databases, of which 295 were excluded for being duplicates. Title and abstract reading excluded 577 out of the remaining 684 studies, and another 10 were excluded after full-text reading. Thus, 97 articles were selected for this study, as shown in Figure 1.

The selected articles were published from 1979 to 2022, with more publications in 2012 and 2016, both with nine studies (Chart 1 of Supplementary Material).

Acoustic analysis was the multidimensional voice assessment measure most used in the studies to verify the effects of the interventions (n = 70, 72.2%), followed by electroglottography (n = 55, 56.7%), self-assessment of the voice (n = 38, 39.2%), aerodynamics (n = 33, 34.0%), APE (n = 22, 22.7%), and laryngeal examination (n = 16, 16.5%) (Table 2) (Chart 1 of Supplementary Material).

As for types, 48 were before-and-after studies (49.5%), 27 were experimental studies (27.8%), 20 were quasi-experimental studies (20.6%), and two were case series (2.1%) (Table 2).

There was a predominance of direct interventions in the studies (n = 85, 87.6%), followed by the combination of direct and indirect interventions (n = 10, 10.3%) and indirect interventions (n = 2, 2.1%) (Table 2).

The total duration of the interventions in the studies ranged from less than 1 minute to 14 hours. The number of sessions ranged from 1 (minimum) to 20 (maximum); 51 (52.6%) studies had a single session (Table 2). Concerning the moment when they assessed the effects of the interventions, 52 (52.6%) studies investigated them immediately, 33 (34.0%) followed up on the participants, and 13 (13.4%) articles did not inform the moment when effects were assessed (Table 2).

The studies' sample sizes ranged from 1 to 154 participants (Table 3), with a predominance of females (n = 1,403, 71.0%), in contrast with only 572 (29.0%) males. The participants' mean age was 27.7±12.9 years (Table 3). Also, 59 (60.8%) studies included nonoccupational voice users, whereas 31 (32.0%) involved occupational voice users, and 7 articles (7.2%) included both occupational and nonoccupational voice users, indistinctly (Table 3).

DISCUSSION

One of the SLH therapists' challenges is to monitor the effects of interventions on their clients. Hence, this research aimed to map voice assessment measures used to verify the effects of interventions in vocally healthy individuals. Such

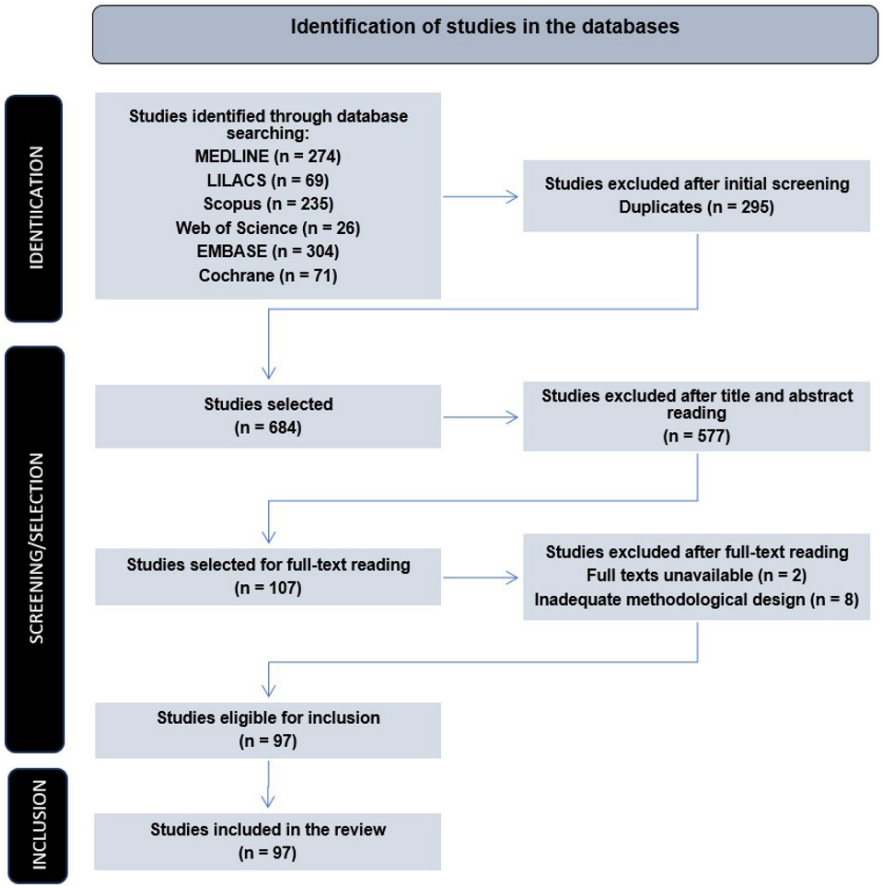

Figure 1. Flowchart of the search and selection of studies that were included in the research
Source: Research data. Based on Page et al.[13]

mapping may help improve the selection of indicators to verify whether goals set at the beginning of training were reached by the end of the process.

Effect measures most used before and after voice training

In general, acoustic analysis was the procedure most used (n = 70, 72.2%) to verify the effects of interventions in vocally healthy individuals – which is accordingly known to be the most investigated assessment procedure regarding the voice[4]. Among the various voice assessment strategies, acoustic analysis had the potential to increase diagnostic precision and quantify changes in voice production before and after the intervention[14].

Although APE and self-assessment protocols are low-cost, easy-to-apply procedures, acoustic analysis provides unique estimates of changes in the process of voice production before and after the intervention. Thus, its contribution is specific, and its information is nonredundant in comparison with other procedures commonly used in vocal clinical practice. In this context, this review identified the different acoustic measures that have been used in interventions in vocally healthy individuals, including fundamental frequency (f0) measures[15-68], intensity measures[18,22,23,25,29-31,37,39,40,43-46,49,53,56-58,61,63,66,67,69-73], cepstral/spectral measures[25,39-41,66,70,73-77], perturbation and noise measures[16,18,22,23,26,27,35,36,38-46,49-52,54-56,60-62,64,65,72,78-85], acoustic indices[16,18,23,41,43-45,49,50,52,72,73,79], and descriptive analysis of narrowband spectrograms[15,17-20,26-28,43-46,51,57,59,69,70,75-77,83,86]. F0 variability stood out among the parameters in the articles that used acoustic assessment to measure the effects of interventions in vocally healthy individuals. In general, f0 variability increased[18,22] after the interventions, indicating a greater voice range in both speaking and singing.

Cepstral/spectral measures were among the most cited ones in the studies. The cepstrum indicates to what extent f0 harmonics are individualized and how they stand out from the noise level present in the signal[87]. In general, CPP (Cepstral Peak Prominence) and CPPS (Cepstral Peak Prominence-Smoothed) values increased after the voice intervention[25,63,66,70,74]. Thus, voice interventions seem to increase the harmonic energy in the voice signal of vocally healthy individuals.

Electroglottography (n = 55, 56.7%) was the second most cited assessment procedure to monitor the effects of the intervention in vocally healthy individuals. This procedure is a low-cost noninvasive technology that measures the vibration activity and changes in the area of contact of the vocal folds during voice production. Given its noninvasive nature, electroglottography is an important alternative to endoscopic imaging and aerodynamic measures in real-time physiological monitoring of voice production.

The most used electroglottography measures were the glottal contact quotient[15,27,29,50,54,70,73,85,88-91], glottal closure quotient[21,28,32,33,35,40,77,92-96], and opening quotient[21,40,92]. In most

Table 2. Description of the studies regarding the characteristics of the interventions and the methods used to assess the effects of the interventions

VARIABLES	STUDIES INVESTIGATED
TYPE OF RESEARCH	
Quasi-experimental	(14, 33, 39, 42, 49, 53, 58, 59, 61, 67, 71, 81, 86, 97, 99, 102, 105, 106, 109, 110)
Before-and-after	(15, 17-22, 25-28, 31, 32, 34-36, 40, 41, 50-52, 54-57, 60, 62, 63, 70, 72-74, 76-80, 82-85, 89-93, 95, 101)
Experimental	(16, 23, 24, 37, 38, 43, 44-48, 64-66, 68, 69, 75, 87, 88, 94, 96, 98, 100, 103, 104, 107, 108)
Case series	(29, 30)
Case study	- - - - -
Type of intervention	
Direct	(14-21, 23-32, 34-58, 60-66, 70-74, 76-89, 91, 92, 94-97, 99, 101-105, 107-110)
Indirect	(22, 106)
Both	(33, 59, 67-69, 75, 90, 93, 98, 100)
TOTAL TIME OF INTERVENTION	
Less than 1 minute	(14, 23, 26, 27, 60, 103)
1-3 minutes	(15, 16, 41-43, 45, 89)
4-10 minutes	(20, 29, 35, 40, 44, 45, 50, 52, 73, 81, 82, 87, 91)
11-20 minutes	(32, 48, 51, 54, 88, 92, 97)
21-30 minutes	(15, 25, 46, 61, 63, 66, 78, 90, 95, 96, 99, 105, 106)
31-40 minutes	- - - - -
41-60 minutes	(83, 93, 94)
1 to 2 hours	(19, 22, 28, 53, 55, 67, 69, 75, 80, 81, 99, 100)
2 to 5 hours	(24, 47)
More than 5 hours	(59, 68, 102, 107)
Information not available	(17, 18, 21, 30, 31, 33, 34, 36-39, 49, 57, 58, 62, 64, 65, 70-72, 74, 76, 77, 79, 84-86, 98, 101, 104, 108-110)
NUMBER OF SESSIONS	
Single session	(14, 20, 21, 24, 26-32, 35, 36, 40-53, 59, 63, 65,69, 70, 73-75, 76, 78-85, 92, 98, 101, 103-106, 108)
2-4 sessions	(15-17, 19, 22, 25, 37, 53, 54, 71, 72, 88, 89, 94-96, 97, 99, 109)
5-8 sessions	(17, 18, 34, 38, 56-58, 66, 68, 86, 87, 94, 97)
9-12 sessions	(60, 62, 67, 75, 93)
13-15 sessions	(106, 107)
8-16 sessions	(23, 67)
16-20 sessions	(91)
Information not available	(33, 39, 61, 64, 77, 90, 100, 102, 110)
MOMENT WHEN EFFECTS WERE ASSESSED	
Immediately	(14, 20, 21, 24, 26-32, 35, 36, 40-53, 57, 59, 60, 64, 66, 70, 71, 73, 74, 76, 78-85, 92, 98, 101, 103-106, 108)
In follow-up	(15-19, 34, 37, 38, 56, 61-63, 65, 67-69, 72, 73, 86-89, 91, 93-97, 99, 100, 102, 107, 109)
Information not available	(22, 23, 25, 33, 39, 54, 55, 58, 59, 75, 77, 90, 110)
ASSESSMENT METHOD	
Self-assessment	(15-18, 22, 23, 28, 32, 33, 38, 45, 53, 55, 58, 59, 63, 66-69, 75, 77, 78, 82, 83, 87, 88, 91, 98-100, 103-107, 109, 110)
APE	(17-19, 31, 46, 48, 58, 61, 70, 78, 79, 82, 88, 91, 93, 95, 96, 99, 100, 102, 106, 107)
Acoustic	(14-17, 19-21, 23, 24, 28, 31-34, 37, 38, 40, 41,43-46, 48, 53, 54, 56-58, 60-71, 73-78, 81-83, 86-89, 91-95, 97-103, 105-107, 109, 110)
Laryngeal examination	(21, 26, 30, 31, 35, 65, 79-81, 88, 93, 95, 100, 102, 106, 108)
Aerodynamics	(16, 18, 20, 27, 29, 31, 32, 37, 44, 46, 54-56, 66-69, 71-73, 80, 82, 83, 88, 89, 97, 99-101, 105-107, 109)
Others	(14, 23-27, 29, 32, 34-36, 39, 40-47, 49-52, 54, 55, 57, 58, 60, 61, 62, 72-74, 76, 79, 83-87, 89, 90, 93, 94, 96, 101-106, 108-110)
TASKS	
Sustained vowel in habitual tone	(14-17, 19, 23, 24-27, 33, 34, 35, 37-39, 41-43, 45, 47, 49, 50, 51, 53-56, 60, 64, 66-68, 70-73, 76, 77, 78, 79, 82, 83, 85, 87-89, 91, 95, 97, 98, 100, 105, 106)
MPT emission (vowel or alveolar fricatives)	(18, 25, 28, 29, 33, 66-69, 75, 81, 91, 94, 100, 102, 105, 106, 108)
Sustained vowel at varied intensities	(20, 21, 33, 43, 45, 46, 51, 67, 87)
Sustained vowel at varied frequencies	(33, 38, 41, 43, 46, 65, 67, 71, 87, 97, 109)
Linked speech at varied intensities	(31, 92, 93, 99, 104)
Linked speech at varied frequencies	(17, 20, 28, 45, 46, 48, 53-56, 58, 59-61, 70, 73, 76, 78, 83, 84, 86, 88-94, 96, 99, 101, 104, 108)
Singing tasks	(17, 20, 48, 51, 57, 62, 63, 74, 83, 86, 88, 93, 97, 99, 102, 107, 109, 110)
Others	(22, 29, 30, 32, 36, 39-46, 49, 51, 52, 59, 62, 63, 71, 72, 78, 80, 84, 85, 87, 94, 96, 103, 104)

Caption: APE = auditory-perceptual evaluation; MPT = maximum phonation time

cases, contact quotient values decreased after the intervention, which may be compatible with a resulting smoother contact between vocal folds.

Voice self-assessment was the third most reported multidimensional assessment procedure to measure the effects of training on healthy voices. There is a complementary relationship

Table 3. Description of the studies regarding the size and characteristics of their samples

VARIABLES	STUDIES INVESTIGATED
SAMPLE SIZE	
Fewer than 30 participants	(14, 17-18, 20-32, 34-43, 45-46, 49-58, 60-63, 65-66, 68, 70-74, 76-77, 80, 82, 85-96, 99, 101, 103-104, 107-108)
30 – 60 participants	(15-16, 33, 44, 47-48, 64, 67, 69,78-79, 81, 83-84, 97-98, 100, 102, 109-110)
60 – 90 participants	(19, 59, 75, 105)
More than 90 participants	(106)
SEX	
Only males	(27, 36, 41-43, 86)
Only females	(18, 20, 23, 28, 31, 37, 40, 46, 49, 59, 62-64, 67-69, 71, 73, 74, 77, 78, 82, 84, 85, 105-107)
Predominantly males	(21, 29, 30, 51, 57, 79, 87, 92, 94, 100, 110)
Predominantly females	(14, 17, 19, 22, 25, 32, 34, 44, 48, 52-56, 70, 78, 80, 81, 83, 88, 91, 96, 99, 102-104, 108)
Equivalent number between sexes	(15, 16, 26, 35, 39, 50, 58, 60, 61, 66, 72, 76, 89, 90, 95, 98, 101, 109)
Information not available	(24, 33, 38, 45, 47, 65, 75, 93, 97)
AGE OF THE PARTICIPANTS	
Under 18 years old	(14)
Mean age between 18 – 25 years	(15, 16, 18, 19, 22, 31-33, 37, 41, 43-45, 66-74, 77, 80, 84, 87, 90, 97, 100, 102, 105, 106, 108, 110)
Mean age between 26 – 40 years	(17, 20, 21, 23, 24, 25-30, 35, 42, 43, 46-48,49, 50-55, 57, 58, 61-64, 75, 76, 78, 79, 81, 83, 88, 89, 93, 95, 98, 108, 109)
Mean age between 40 – 60 years	(59, 91, 92, 101, 103, 104)
Above 60 years old	(34, 38, 50, 56, 60, 82, 94)
Information not available	(36, 39, 40, 65, 85, 86, 96, 99, 107)
OCCUPATIONAL VOICE USE	
Occupational voice users	(17, 19, 22, 26, 28-30, 32-33, 46, 48, 57, 59-61, 66, 73-75, 77, 83-85, 87, 88, 91, 92, 99-102)
Nonoccupational voice users	(14-16, 18, 20, 21, 23-25, 27, 31, 34, 37-41, 44, 45, 47, 49-56, 58, 62-65, 67-72, 76, 78-82, 86, 89, 90, 93, 94, 96-98, 103, 105-108, 110)
Mixed samples	(35-36, 42, 43, 95, 104, 109)

between laryngeal diagnosis, APE, and voice self-assessment in the process of confirming diagnoses and monitoring individuals with voice complaints, whether dysphonic or vocally healthy[97]. Self-assessment provides unique information on the limitations and impacts the person experiences because of their voice problem. Naturally, most validated voice self-assessment instruments are sensitive only to dysphonic populations and may have limited applications in vocally healthy individuals.

In the studies approached in this review, the visual analog scale[16,30,38,41,51,53,74,81,98] was the most used tool to measure voice self-perception before and after the intervention. There was great variability in the construct measured with this scale, ranging from the intensity/frequency of symptoms to the perceived effort associated with voice production. This can be explained in that most self-assessment protocols were validated for dysphonic populations and may not respond to interventions in vocally healthy individuals.

Aerodynamic assessments were the fourth most cited procedure in these studies. Extracting the maximum phonation time (MPT) in seconds was the most used strategy[16,18,23,24,50,52,55,60,62,64,65,70,72,98], which can be justified by the seemingly simple collection procedure, waiving the use of high-cost technological devices. Vocally healthy individuals in the studies[16,24,55,60,62] significantly increased their MPT after the voice intervention. Even though MPT is traditionally used as a voice assessment measure, its values tend to vary greatly within and between subjects, which may limit its use to measure effects. The recommendation is that MPT be interpreted along with other voice assessment measures, such as acoustic and other aerodynamic measures, always integrated with the client's complaints and demands[99].

APE was the fifth most cited assessment procedure. In SLH clinical practice, APE and acoustic analysis are the most used voice assessment procedures[3]. Of the 97 investigated studies, 12 reported changes in the participants' APE after the voice training[17,31,39,46,52,63,71,72,78,85,100,101]. In general, the degrees of hoarseness[56,57,62] and breathiness[31,52,56] decreased after the voice intervention. These data help understand the need for APE metrics to monitor the effects of training in vocally healthy individuals, as hoarseness and breathiness are more associated with dysphonic voices.

Laryngeal visual examination analysis was the multidimensional assessment procedure least used to monitor the effects of voice training in vocally healthy individuals[19,42,52,58,65,72,84,98,101-104] (n = 16, 16.5%). The low number of studies may be justified by the examination being expensive and invasive. Moreover, in vocally healthy populations that seek an SLH therapist to improve their voice production, a laryngeal visual examination is usually performed only at the beginning of the treatment to confirm the absence of structural, functional, or vibratory changes in the larynx. In most cases, the post-treatment laryngeal visual examinations revealed greater laryngeal lowering, greater pharyngeal opening[19], improved glottal closure[98], and more elongated vocal folds in ascending glissando tasks[95].

Characterization of selected studies

There was great methodological variation among the 97 studies selected for this research. Almost half of them (n = 48, 49.5%) were before-and-after studies. These findings reinforce the importance of conducting randomized clinical trials on voice training in vocally healthy individuals to strengthen the base of evidence in the area. Before-and-after studies can have more exploratory results, favoring exploratory analyses or speculations on the effects of training in the study population.

Also, most studies (n = 85, 87.6%) used direct interventions, and many studies used a single training session (n = 51, 52.6%),

and assessed only the immediate effect of voice training (n = 52, 52.6%). The total intervention time ranged from less than 1 minute to 14 hours of training distributed in the sessions.

The predominance of direct interventions strengthens the understanding of specialists in the area that voice training must use strategies to mobilize physiological, biomechanical, and aerodynamic parameters related to efficient voice production in this population. The number and time of sessions varied greatly between studies, which reinforces that training for vocally healthy individuals is individualized and focused more on the effects of individual exercises than programs for the overall development of vocal efficiency. Furthermore, many studies measured the immediate effects without following up on the participants to verify whether vocal behaviors and adjustments had been transferred to everyday situations. This field of practice does not yet have well-defined parameters for training programs aimed at vocally healthy individuals, giving priority to individualized programs – which may limit the comparison of effects.

Differences in training time hinder the summarization and comparison of the effects of strategies and techniques used in the studies. Moreover, training must respect aspects related to the physiology of exercise, structuring the sequence and dosage of exercises, the number of series, and the training period[105].

The number of participants in the studies varied greatly (minimum of one and maximum of 154), with a predominance of women (n = 1,403, 71.0%) and nonoccupational voice users (n = 59, 60.8%), and with a mean age of 27.7±12.9 years. The possible limitation in sample size can impact the generalization of results to other populations. The predominance of women is seemingly consonant with the fact that females seek such treatment more often either for rehabilitation or voice training.

Women generally seek healthcare more often than men and correspond to a higher percentage of referrals to voice clinical services[106]. Moreover, women usually have greater contact with health services not only to seek attention in the various areas of healthcare and prevention but also to accompany their children, husbands, parents, and other relatives. Therefore, women have greater access to and knowledge of the various healthcare programs. Access to information ensures to this population greater participation in different types of healthcare treatment. Hence, voice care research and programs tend to reach women first.

The mixed public in the studies addressed in this review, encompassing occupational and nonoccupational voice users, was also expected, as vocally healthy individuals traditionally seek SLH therapists with a specific need in either speaking or singing. Lastly, the mean age – most studies involved participants aged 18-40 years – seems to reflect the interest in understanding the effects of intervention in young adults. The few studies with participants above 40 years old may exclude women undergoing hormonal changes typical of menopause. However, since individuals above 40 years old are socially and professionally active in the modern world, it is important to reflect on the exclusion of this population in intervention studies approaching vocally healthy individuals.

The mapping conducted in this research may indicate the need to plan further research as randomized clinical trials, necessarily including sample calculation and participant randomization to make up the experimental and control groups, besides broadening the sample for it to be representative, for instance, of the professionally active population. Moreover, there is a great variability of measures to assess the effects of interventions in vocally healthy individuals.

Unlike the clinical assessment and monitoring of dysphonic patients, there seems to be no consensus or recommendations on a set of essential measures to assess the effects of voice training in vocally healthy individuals. This probably reflects the historical makeup of the area of voice, which aims at rehabilitating dysphonia or preventing it in at-risk populations, such as teachers.

There is a lack of robust studies with evidence on strategies and programs to improve voice production in vocally healthy individuals. Therefore, developing a consensus on the best set of measures and tasks to verify the effects of interventions and the program approaches to be implemented may be a feasible initial way to better structure the SLH practice with healthy voices.

CONCLUSION

The studies included in the review used a variety of measures to assess healthy voices. Acoustic analysis is the most used procedure to monitor the effects of interventions in vocally healthy individuals, followed by electroglottography, voice self-assessment, aerodynamic assessment, APE, and laryngeal visual examination.

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Supplementary Material

This article is accompanied by supplementary material:

Chart 1. Measures used to assess the effects of interventions cited by the studies, per dimension of voice assessment.

This material is available as part of the online version of the article from: https://doi.org/10.1590/2317-6431-2022-2769en