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Vocal analysis in children: an integrative review

Análise vocal na infância: uma revisão integrativa

Análisis Vocal en la infancia: una revisión integradora

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Abstract

Objective: *to perform an integrative literature review about the characteristics of normal and dysphonic voices and the prevalence of vocal cords lesions in children.* ***Methods:*** *it is a literature integrative review. The survey of scientific articles was carried out through data bases Medline, LILACS, IBECS (through the VHL Search Portal), PubMed and ISI Web of Science. In the search of the articles were used the descriptors "Voice Disorders", "Dysphonia", "Hoarseness", "Voice Quality", "Speech Acoustics", "Voice", "Phonation", "Vocal Cords", "Pediatrics", "Child", "Child Preschool". For the analysis of the data, the information collected was organized in a concise manner in a database, being performed in a descriptive way, considering the information about the sample, objectives, methodology and main results, and organized by content similarity.* ***Results:*** *770 articles were identified, of which 36 were directly related to objective of the review and were analyzed.* ***Conclusions:*** *the vocal quality of children without vocal changes is characterized by fundamental frequency values that decrease with increase of age and with differences in relation to gender. The maximum phonation time increases with age. In dysphonic children the vocal quality is blow and rough, with a grade of alteration from mild to moderate; the acoustic measures of the voice, the maximum phonation time values are altered; the fundamental frequency is severe. The cyst is vocal cords lesion most prevalent up to six years age, and after this age is the vocal nodule.*

Keywords: *Voice Disorders; Dysphonia; Voice Quality; Voice; Child.*

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Authors' contributions: LAR was responsible for the bibliographic search, manuscript drafting, study conception and design; BOS was responsible for the bibliographic search and manuscript drafting; ACCG was responsible for overseeing all the stages of the study's development, as well as for the study's conception and design.

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Resumo

Objetivo: *realizar uma revisão integrativa de literatura sobre as características de vozes normais e disfônicas e a prevalência de lesões nas pregas vocais em crianças.* ***Métodos:*** *trata-se de uma revisão integrativa da literatura. Foi realizado o levantamento dos artigos científicos por meio das bases de dados Medline, LILACS, IBECS, PubMed e ISI Web of Science. Na busca dos artigos foram utilizados os descritores "Distúrbios da Voz", "Disfonia", "Rouquidão", "Qualidade da Voz", "Acústica da Fala", "Voz", "Fonação", "Pregas Vocais", "Pediatria", "Criança", "Pré-Escolar". Para a análise dos dados, as informações coletadas foram organizadas de maneira concisa em um banco de dados, realizado de forma descritiva, considerando as informações referentes à amostra, objetivos, metodologia e resultados principais, e organizadas por similaridade de conteúdo.* ***Resultados:*** *foram identificados 770 artigos, dos quais 36 estavam diretamente relacionados ao objetivo da revisão e foram analisados.* ***Conclusões:*** *a qualidade vocal das crianças sem alterações vocais é caracterizada por valores de frequência fundamental que decrescem com o aumento da idade e com diferenças em relação ao sexo. O tempo máximo de fonação aumenta com a idade. Em crianças disfônicas a qualidade vocal é soprosa e rugosa, com grau de alteração de leve a moderado; as medidas acústicas da voz, os valores de tempo máximo de fonação estão alterados; frequência fundamental é reduzida ou os valores de frequência fundamental observados em crianças com alteração foram mais baixos do que os valores da normalidade. A lesão de prega vocal mais prevalente até seis anos de idade é o cisto e, após esta idade, é o nódulo vocal.*

Palavras-chave: *Distúrbios da Voz; Disfonia; Qualidade da Voz; Voz; Criança.*

Resumen

Objetivo: *Realizar una revisión integradora de la literatura sobre las características de vozes normales y disfonicas y la prevalencia de lesiones de las cuerdas vocales en niños.* ***Métodos:*** *se realizó una investigación integrativa de la literatura a través de articulos cientificos enontrados en las bases de datos Medline, LILACS IBECS, PubMed y ISI Web of Science. En busca de artículos se utilizaron los descriptores "Trastornos de la Voz", "Disfonía", "Ronquera", "Calidad de la Voz", "Acústica del Habla", "Voz", "Fonación", "Pliegues Vocales", "Pediatría", "Niño", "Preescolar". Para el análisis de datos, la información recogida se organizó de manera concisa en una base de datos realizada de una manera descriptiva, teniendo en cuenta la información sobre la muestra, objetivos, metodología y resultados principales, organizados por la similitud del contenido.* ***Resultados:*** *fueron identificados 770 artículos de los cuales 36 estaban directamente relacionadas con el objetivo de la revisión y fueron analizados.* ***Conclusiones:*** *La calidad vocal de los niños sin trastornos vocales se caracteriza por la disminución de la frecuencia vocal fundamental con el aumento de la edad y con diferencias en relación al sexo. El tiempo máximo de fonación aumenta con la edad. Los niños con disfonía tienen una calidad de voz susurrante y rugosa, con un grado de alteración de leve a moderada; las medidas acústicas de la voz, y los valores de tiempo máximo de fonación están alterados. La frecuencia fundamental es reduzida o los valores de frecuencia fundamental obsevados en niños com alteración, fueron mas bajos que los valores de normalidad. La lesión de pliega vocal más prevalente hasta seis años de edad es el quiste. Después de esta edad son los nódulos vocales.*

Palabras clave: *Trastornos de la Voz; Disfonía; Calidad de la Voz; Voz; Niño.*

Introduction

The prevalence of voice alterations in children ranges from 6% to 38%, 92% of which may be dysphonias caused by vocal misuse, as the most prevalent vocal fold lesions among the pediatric population are functional ones[2]. Nodules (53%) and cysts (21%) are present in 67% of the children with vocal complaints. Incomplete glottal closures of the posterior (11%), mid-posterior (39%) and double (17%) triangular types are also highly prevalent among children[1].

Children's and young women's larynges have lower glottal proportions when compared to those of young males. However, children's glottal proportion is still lower than women's, which makes

children prone to incomplete posterior triangular glottal closure. This suggests that the pediatric population is highly susceptible to develop lesions due to vocal trauma to the middle third of the vocal folds[3,4].

Despite the unique characteristics of children's voices and the high prevalence of dysphonia in childhood, studies describing children's vocal and laryngeal features are scarce and need to be analyzed for a better understanding of the vocal clinical practice among the pediatric population.

The purpose of this study was to conduct an integrative review of the literature on the characteristics of normal and dysphonic voices and the prevalence of vocal fold lesions in children.

Method

This is an integrative review of the literature on vocal quality in childhood. The method adopted followed the six stages proposed by the literature of the integrative review process: 1) preparing the guiding question, 2) searching the literature, 3) determining the studies' features, 4) critical analysis of the studies included, 5) discussion of results, and 6) presentation of the review[5,6].

The present study's guiding question was: what has been the knowledge production regarding voice quality and vocal fold lesions among the pediatric population?

The collection of scientific articles was conducted by searching the Medline, LILACS, IBECS (through the BVS portal), PubMed and ISI Web of Science databases. In the search of the articles the descriptors *"Voice Disorders", "Dysphonia", "Hoarseness", "Voice Quality", "Speech Acoustics", "Voice", "Phonation", "Vocal Cords", "Pediatrics", "Child",* and *"Preschool Child"* were used, in English, Portuguese, Spanish and a combination thereof.

The inclusion criteria were the following: scientific articles published between 2001 and 2016 in English, Portuguese and Spanish addressing the issue of vocal quality and vocal fold lesions among the pediatric population. The criteria for exclusion from the study were: articles with access to the abstract only, repeated citations on the databases, and articles not directly associated with the purpose of the investigation.

The articles found were analyzed independently by two researchers to determine whether they met the inclusion criteria. Whenever the two researchers disagreed as to an article's relevance to the study, the article in question was analyzed by consensus.

The data collected were concisely organized on a database considering the information referring to the sample, objectives, method and main results, and broken down per similarity of content.

After analyzing the articles selected, these were categorized according to characteristics of vocal quality in children with normal and dysphonic voices as well as the characteristics of the most prevalent vocal fold lesions in dysphonic children.

Results

770 articles were analyzed, from which only 36 were directly associated with the guiding question and were therefore selected for the study. The results from this analysis are described in Figure 1.

Among the studies included in this review, none had similar methods, which rendered it impossible to conduct a meta-analysis of the findings.

The analysis of the publications allowed for the identification of two main themes, as seen in Figure 2: children with normal voices (vocal quality) and dysphonic children (vocal quality and vocal fold lesions).

The results of the literature review, including the case-based reasoning and the results found, are presented in Chart 1.

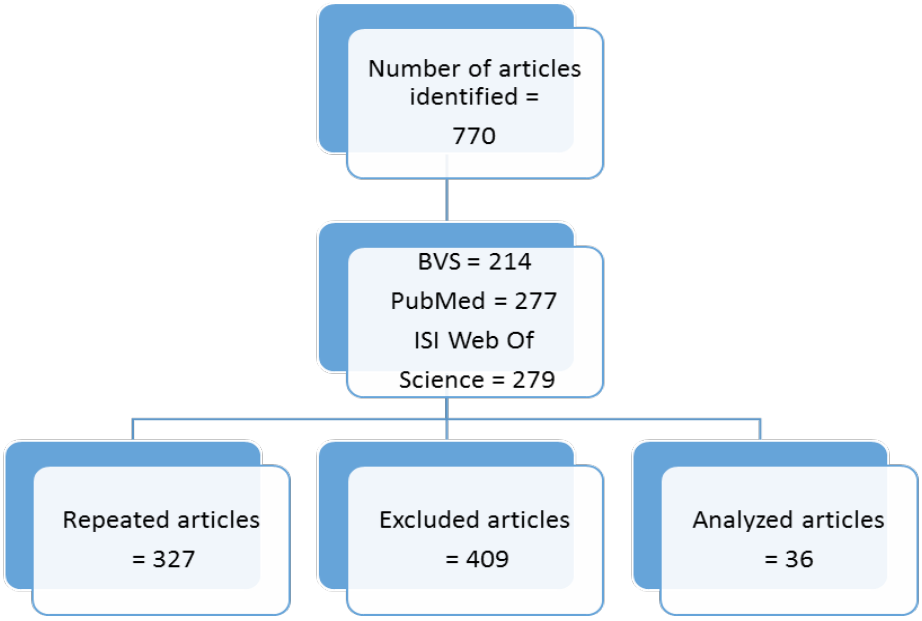


Figure 1. Article selection and analysis

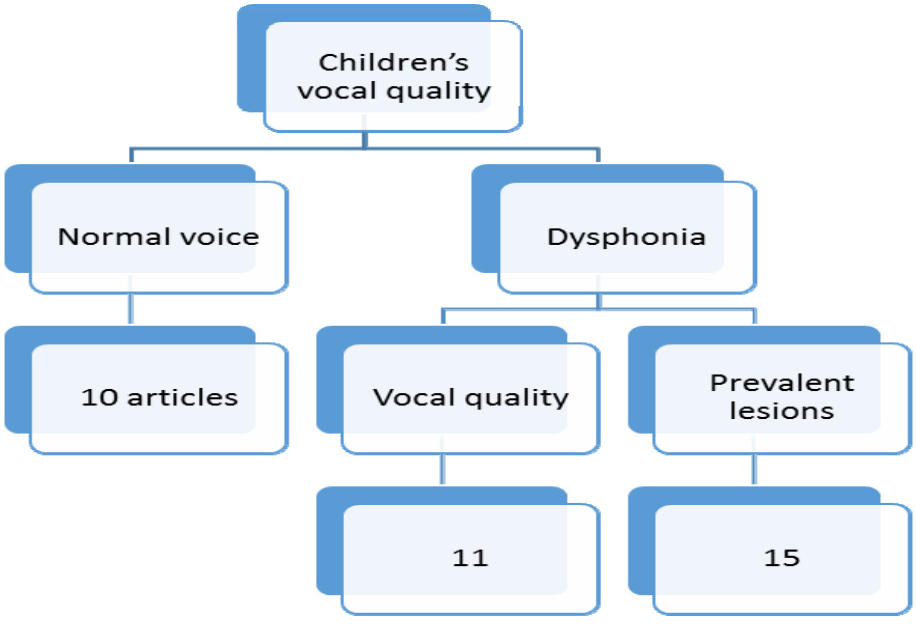


Figure 2. Articles subdivided according to theme

Chart 1. Articles selected for the literature review.

AUTHORS/YEAR	DESIGN	NUMBER AND AGE OF SUBJECTS	EVALUATION	RESULTS
Oliveira RC, Teixeira LC, Gama ACC, Medeiros AM. (2011)[1]	Cross-sectional study	70 children between the ages of 6 and 10 years	Auditory-perceptual analysis (GRBASI scale) Acoustic analysis	Most common vocal quality among dysphonic children: breathiness, followed by roughness. APQ, PPQ and NHN acoustic measures: higher among dysphonic children.
Hill CA, Shilpa O, Maturo S, Maurer R, Bunting G, Hartnick CJ. (2013)[7]	Prospective longitudinal study	50 participants between the ages of 4 and 17 years	Acoustic analysis	Mean fundamental frequency in subjects from 4 to 17 years of age: 244 Hz.
Cappellari VM, Cielo CA. (2008)[8]	Cross-sectional study	23 children between the ages of 4 and 8.5 years	Auditory-perceptual evaluation (RASAT scale) Acoustic analysis	The frequency variation (vf0) and the noise/Harmony noise (NHR) were higher in the total sample than among 5- and 6-year olds; as age increased, NHR decreased; as PPQ increased, the vf0, amplitude variation (vAm), soft phonation index (SPI) and NHR also increased; and as the PPQ, APQ and voice turbulence index (VTI) increased, the soft phonation index (SPI) decreased.
Viegas F, Viegas D, Atherino CCT, Baeck HE. (2010)[9]	Cross-sectional study	207 children between the ages of 4 and 8 years	Auditory-perceptual analysis Acoustic analysis	The fundamental frequency decreased as age increased. The age of 6 years was appointed as a determinant of the acoustic changes in children's vocalizations.
Infusino SA, Diercks GR, Rogers, DJ, Garcia J, Ojha S, Maurer R, Bunting G, Hartnick CJ. (2015)[10]	Cross-sectional study	218 participants between the ages of 4 and 17 years	Acoustic analysis	Significant decrease in fundamental frequency among boys with normal voices between the ages of 11 and 14 years. Among the girls, the study found a tendency toward linear decrease in fundamental frequency, without any age threshold.
Hunter EJ. (2009)[11]	Case study	One child, aged 5 years and 7 months	Acoustic analysis	This study's findings show that children may produce a notably different voice during clinical observations as compared to their regular daily routines.
McAllister A, Brandt SK. (2012)[12]	Experimental	11 children aged 5 years	Acoustic analysis	When the mean fundamental frequency of controlled emissions was compared to that of spontaneous speech, the latter was significantly higher. This suggests that controlled recording conditions may be inadequate to characterize the vocal behavior of children in a natural environment.
Baker S, Weinrich B, Bevington M, Schroth K, Schroeder E. (2008)[13]	Experimental	48 participants between the ages of 6 and 10 years	Acoustic analysis	The results indicated that the type of task has a significant influence on children's fundamental frequency values. This frequency was higher when counting numbers and sustaining vowels, as compared to phrases and sentences.
Brockmann-Bauser M, Beyer D, Bohlender JE (2015)[14]	Cross-sectional study	68 children between the ages of 5 years and 9 years and 11 months	Acoustic analysis	In children with normal voices, the acoustic measures of fundamental frequency, jitter and shimmer were different in regular and controlled emissions. The fundamental frequency was higher, whereas jitter and shimmer were lower among girls. The variables gender, age, height and weight did not interfere in the fundamental frequency, jitter and shimmer values in controlled emissions.
Brockmann-Bauser M, Beyer D, Bohlender JE (2014)[15]	Cross-sectional study	49 children between the ages of 5 years and 9 years and 11 months	Acoustic analysis	When comparing regular and controlled emissions of children with normal voices, the study found that the acoustic measures of jitter and shimmer were lower in emissions of 80 dBA.
Tavares EM, Labio RB, Martins RHG (2010)[16]	Cross-sectional study	240 participants between the ages of 4 and 12 years	Auditory-perceptual analysis Acoustic analysis Laryngeal Videostroboscopy	As age increased, there was a decrease in fundamental frequency and APQ, and an increase in SPI. The voice parameters did not differ between the genders up to the age of 12.

AUTHORS/YEAR	DESIGN	NUMBER AND AGE OF SUBJECTS	EVALUATION	RESULTS
Cielo CA, Cappellari VM. (2008)[17]	Cross-sectional study	23 children between the ages of 4 years and 6 years and 8 months	Auditory-perceptual evaluation (RASAT scale)	MPT values were higher at the age of 6 than at the age of 4. As age increased, all MPT values also increased, and the s/z ratio for all ages was close to one.
Tavares EM, Brasolotto A, Santana MF, Padovan CA, Martins RHG. (2009)[18]	Cross-sectional study	2,000 children between the ages of 4 and 12 years	Auditory-perceptual analysis (GRBASI scale) Acoustic analysis Video Laryngoscopy	There was a decrease in fundamental frequency as age increased, and acoustic parameters were higher among dysphonic children. When laryngoscopies were performed, the researchers found nodules, thickenings and inflammation. The parents' perceptions indicated prevalence of dysphonia in 6.15% and perceptive analyses in 11.4%.
Simões-Zenari M, Nemr K, Behlau M (2012)[19]	Cross-sectional study	100 participants between the ages of 4 years and 6 years and 11 months	Auditory-perceptual analysis Acoustic analysis	The group of dysphonic children showed a higher prevalence of breathiness and roughness. The fundamental frequency was lower among dysphonic children, and the noise component was higher in that same group.
Lopes LW, Lima ILB, Almeida LNA, Cavalcante DP, Almeida AAF. (2012)[20]	Cross-sectional study	71 children between the ages of 3 and 10 years	Auditory-perceptual analysis Acoustic analysis	None of the children showed a severe vocal deviation. There was a higher frequency of occurrence of mild deviation in the instability, roughness and strain parameters. The moderate general degree, roughness and breathiness were correlated with the higher shimmer value and lower GNE value.
Ingrid V, Dominique M, Marc R. (2012)[21]	Experimental	42 children between the ages of 5 and 13 years	Pediatric Voice Symptom Questionnaire (PVSQ)	The PVSQ questionnaire is a valid and reliable instrument for self-evaluation of children's dysphonia.
Johnson K, Brehm SK, Weinrich B, Meinzen-Derr J, Alarcon A. (2011)[22]	Retrospective observational study	38 participants between the ages of 4 years and 2 months and 17 years and 2 months	Pediatric Voice Handicap Index (pVHI) Auditory-perceptual analysis (CAPE-V scale)	The study found a correlation between CAPE-V and functional pVHI CAPE-V, as well as between strain and breathiness and overall and functional pVHI. The auditory-perceptual parameter with the highest degree of alteration was breathiness, followed by roughness, even though strain and instability were also altered.
Shah RK, Engel SH, Choi SS. (2008)[23]	Retrospective longitudinal study	40 children averaging 7.5 years of age	Auditory-perceptual analysis Acoustic analysis	There was no association between the size of nodules and fundamental frequency, shimmer, decreased respiratory support, air loss, or muscle tension. The size of nodules influences the pitch, in that the larger the lesion, the lower the pitch.
Nardone HC, Recko T, Huang L, Nuss RC (2014)[24]	Retrospective clinical study	67 participants between the ages of 3 years and 8 months and 20 years and 6 months	Auditory-perceptual analysis Laryngeal Videostroboscopy	Children with vocal fold nodules show a degree of alteration in vocal quality proportionate to the size of their lesions.
Lopes LW, Lima IL, Barbosa AE, Heitmann M, Silva MF, Bonfim L, Silva POC (2015)[25]	Cross-sectional study	93 participants between the ages of 8 and 10 years	Auditory-perceptual analysis (analogical visual scale) Acoustic analysis	74.1% of participants showed a mild voice alteration in the roughness and breathiness parameters. 14% of them had a moderate degree of deviation, and only 11.9% of subjects had healthy voices.
Reynolds V, Buckland A, Bailey J, Lipscombe J, Nathan E, Vijayasekaran S, Kelly R, Maryn Y, French N. (2012)[26]	Prospective observational study	97 children between the ages of 6 and 15 years	Auditory-perceptual analysis Acoustic analysis through the Acoustic Voice Quality Index (AVQI)	Extremely premature subjects showed alterations in both the acoustic and auditory-perceptual analyses when compared to children born at full term. The AVQI is a precise diagnostic tool for the pediatric population, suggesting that it is an adequate evaluation instrument to determine the presence and degree of pediatric voice disorders.
Walz PC, Hubbell, MP, Elmaraghy, CA (2014)[27]	Prospective observational study	69 children averaging 28 months of age	Pediatric Voice Outcomes Survey (pVOS) Pediatric Voice-Related Quality of Life (PVRQOL)	Premature subjects with longer intubation periods have their voice quality more negatively affected. The PVRQOL score was positively correlated with the gestational term and negatively correlated with the intubation period.

AUTHORS/YEAR	DESIGN	NUMBER AND AGE OF SUBJECTS	EVALUATION	RESULTS
Lábio RB, Tavares ELM, Alvarado RC, Martins RHG. (2012)[28]	Retrospective observational study	120 children between the ages of 4 and 12 years	Auditory-perceptual analysis Acoustic analysis	The voice quality of children with nasal obstruction showed more insufficient nasal resonance, lower pitch and compressed voice. The acoustic analysis showed that the fundamental frequency is always lower in the group with chronic nasal obstruction, and the jitter, shimmer and NHN measures are better among the group without nasal obstruction.
Lundeborg I, Hultcrantz E, Ericsson E, McAllister A. (2012)[29]	Randomized retrospective clinical study	189 children between the ages of 50 and 65 months	Auditory-perceptual analysis Acoustic analysis	Voice quality is perceptually and acoustically affected by adenotonsillar hypertrophy. After surgery voice returns to normal, but the acoustic differences remain.
Gramuglia ACJ, Tavares ELM, Rodrigues AS, Martins RHG (2014)[30]	Cross-sectional study	200 participants between the ages of 4 and 11 years	Auditory-perceptual analysis Acoustic analysis Laryngeal Videostroboscopy	When comparing the voices of children with vocal fold nodules to children without laryngeal alterations, the study found that the degree of alteration, roughness and breathiness were higher among children with the lesion. The acoustic jitter, shimmer, PPQ, APQ and NHN were higher in the group with vocal nodules. There was no difference in the fundamental frequency values.
Garcia-Real T, Diaz-Roman TM, Garcia-Martinez V, Vieiro-Iglesias P (2013)[31]	Cross-sectional study	51 children between the ages of 6 and 15 years	Auditory-perceptual analysis Acoustic analysis	Children diagnosed with ADHD displayed hoarseness and neck strain when compared to the children in the control group.
Beber BC, Cielo CA, Siqueira MA. (2009)[32]	Prospective observational study	54 children between the ages of 13 and 15 years	Auditory-perceptual analysis	Among the female children, the maximum phonation times were considered short. Among the boys with mass lesions, 50% had MPTs considered normal, and the other 50% had short MPTs.
Melo ECM, Mattioli FM, Brasil OC, Behlau M, Pitaluga ACA, Melo DM. (2001)[33]	Non-randomized retrospective clinical study	34 children between the ages of 4 and 13 years	Video Laryngoscopy	Vocal nodules were the most common lesion found in the children evaluated, with no differences between the sexes, and with a mean age of 9 years.
Martins RHG, Ribeiro CBH, Mello BMZ, Branco A, Tavares ELM. (2012)[34]	Prospective clinical study	304 participants between the ages of 4 and 18 years	Laryngeal Videostroboscopy	Dysphonia happened in male children between the ages of 7 and 12. The most frequent lesions were vocal nodules and epidermoid cysts.
Connelly A, Clement WA, Kubba H. (2009)[35]	Retrospective clinical study	142 children between the ages of 7 and 12 years	Laryngeal mirror, laryngoscopy and microlaryngoscopy-bronchoscopy	Epidermoid cysts are associated with congenital dysphonias, present in 7% of cases. Vocal abuse is one of the factors that correlate with the development of lesions due to vocal trauma, and, more specifically, to the development of vocal nodules.
Mortensen M, Schaberg M, Woo P. (2010)[36]	Retrospective clinical study	80 participants between the ages of 3 and 17 years	Laryngeal Videostroboscopy	Among children under 6 years of age, the main cause of voice alterations is the presence of minimal structural alterations.
Kallvik E, LindströmE, Holmqvist S, Lindman J, Simberg S (2015)[37]	Cross-sectional study	217 children between the ages of 6 and 10 years	Auditory-perceptual analysis (analogical visual scale)	The prevalence of dysphonia among school children was 12.0%. In girls, the prevalence was 7.8%, and in boys it was 15.8%. Roughness was the most prevalent auditory-perceptual parameter.
Stivanin L, Santos FP, Oliveira CCC, Santos B, Ribeiro ST, Scivoletto S (2015)[38]	Cross-sectional study	136 children averaging 10 years and 2 months of age	Auditory-perceptual analysis (GRBASI scale)	Voice alterations were present in 67.6% of children victims of abuse treated at a health center. The prevalence of voice alterations was higher among the group under study than among the general population.
Smillie IMK, Cohen W, Lawson E, Wynne DM (2014)[39]	Prospective clinical study	195 participants aged 5, 8 and 11 years	Auditory-perceptual analysis (GRBASI scale) Pediatric Voice-Related Quality of Life (PVRQOL)	52% of children were diagnosed with nodules in their vocal folds, predominantly male children. 69% of dysphonia cases displayed musculoskeletal stress disorder.
Mackiewicz-Nartowicz H., Sinkiewicz A, Bielecka A. (2011)[40]	Cross-sectional study	150 children between the ages of 2 years and 5 months and 14 years	Laryngeal Videostroboscopy	56.7% of children had vocal fold nodules. The rest (40%) of the children were diagnosed as having functional dysphonia.

AUTHORS/YEAR	DESIGN	NUMBER AND AGE OF SUBJECTS	EVALUATION	RESULTS
Bhattacharyya N (2015)[42]	Prospective clinical study	An estimated 839±89 thousand participants between the ages of 23 and 17 years	Specific questionnaire	Approximately 839,000 children (1.4%) treated at a health center in 2012 reported voice issues. Overall, 53.5% were diagnosed. Laryngitis (16.6%) and allergies (10.4%) were the most common diagnoses. 16.4% classified their problem as "big" or "very big".
Maia AA, Gama ACC, Kümmer AM (2014)[43]	Integrative literature review	07 articles with children between the ages of 8 and 11 years	Search for scientific articles on the LILACS, IBECS, MEDLINE, Biblioteca Cochrane, SciELO and Web of Science ISI databases	The integrative review did not find a behavioral profile among dysphonic children, nor did it find an association between child dysphonia and inadequate vocal behavior.

Discussion

Children with normal voices

1. Vocal quality

The vocal quality of children with no vocal or laryngeal alterations was present in ten (29.41%) of the studies included in this review.

One study analyzed the fundamental frequency (f0) in subjects between 4 and 17 years of age and obtained a global mean of 244 Hz[7].

Some articles[8,9] subdivided the children into age brackets, and each bracket's f0 mean is described in Table 1. There was a consensus among the results, evidencing that as age increased, the f0 of children without alterations decreased[8,9]. One study found that, when comparing the f0 means among the groups, 6 years is the threshold for a significant reduction of the f0[9]. Another study showed a decrease in the f0 among boys between 11 and 14 years old[10], characterized as the period for vocal change. A tendency towards linear decrease in the f0 was found among girls; however, no significant reduction was found in any age threshold[10]. These results suggest that the vocal change process is less marked in girls' f0.

Table 1. Fundamental frequency by age brackets.

Age bracket	Fundamental frequency mean (F0)[08-10]
4 years to 5 years and 11 months	255 Hz to 275 Hz
6 years to 7 years and 11 months	233 Hz to 248 Hz
8 years to 9 years and 11 months	230 Hz to 238 Hz
10 to 12 years	234 Hz

Two studies[11,12] compared the f0 means in the controlled emission and in the spontaneous speech, and the results indicated that the f0 was significantly higher in spontaneous speech. Another study[13] analyzed the influence of the task requested on the voices of children between 5 years old and 7 years and 11 months old without voice alterations. The f0 was considerably higher when counting numbers and sustained vowels, when compared to phrases and sentences[13]. When compared to controlled emissions, the jitter and shimmer acoustic measures in vocally healthy children were significantly higher in regular emissions[14,15]. The results found in the literature evidenced that anatomical changes undergone by the larynx during children's growth alter the f0, particularly after 6 years of age[16]. Another finding was that f0 is a speech task--dependent acoustic parameter, and that its analysis, considering connected speech, is higher because it is influenced by prosodic aspects[11].

The acoustic measures of frequency periodicity and short-term intensity among non-dysphonic children were also analyzed in three studies[8,9,16] by means of the software Multi Dimensional Voice Program (MDVP) of Kay Pentax®, and presented per age bracket in Table 2.

Table 2. Acoustic measures by age brackets.

Acoustic measures[8,9,16]	4 to 5 years	6 to 7 years	8 to 9 years	10 to 12 years
PPQ%	0.85 to 1.21%	0.9%	0.95%	1.01%
APQ%	3.13 to 8.1%	3.56 to 5.51%	3.28%	2.85%
NHN	0.13 to 0.26	0.13 to 0.17	0.13	0.13

Legend:
PPQ – Pitch Perturbation Quotient
APQ – Amplitude Perturbation Quotient
NHN - Noise/Harmony Noise

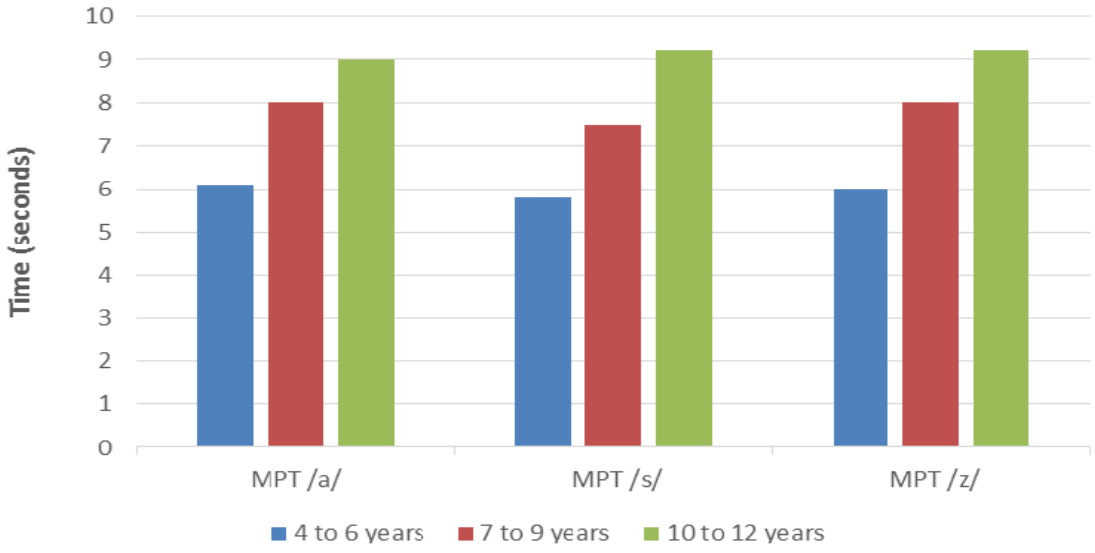
The literature findings suggest that the acoustic measures of pitch perturbation quotient (PPQ), amplitude perturbation quotient (APQ) and the noise measures, such as noise/harmony noise (NHN), are not affected by the larynx development during childhood, indicating that the vibration of the vocal folds does not become more stable and periodic with age[8].

The maximum phonation time (MPT) among the pediatric population were the objects of two studies[17,18], one of which analyzed the MPTs in children between the ages of 4 and 6 (Figure 3).

Legend: MPT = maximum phonation time

Figure 3. Maximum phonation time by age[17]

By dividing the children into age brackets of 4-6 years, 7-9 years, and 10-12 years, another study[18] found a slight difference between the MPT means, described in Figure 4. Both studies concluded that the MPTs increased proportionally according to age; however, a significant increase was only found after 9 years of age[17,18]. These results suggest that the anatomical development of the larynx and the lungs have a positive impact on MPT measures, with a progressive increase up to 9 years of age, after which this anatomic growth slows down, with a smaller interference in MPT values, which will be affected the most during the vocal change period.



Legend: MPT = maximum phonation time

Figure 4. Maximum phonation time by age bracket[18]

Dysphonic children

1. Vocal quality

The literature[1,19,20] shows that the auditory-perceptual parameter with the highest degree of alteration among children with functional dysphonia is breathiness, followed by roughness, even though strain and instability were also altered.

A negative vocal self-perception is more marked among dysphonic children than among children with no vocal disorders. The overall degree of dysphonia, roughness, breathiness and strain affect mainly the functional domain, whereas breathiness also influences the quality of life emotional domain[1,21,22,23].

Two studies concluded that in children with nodules in their vocal folds the degree of alteration of their vocal quality is proportional to the size of the nodular lesion[24].

One article[25] associated the degree of dysphonias to the auditory-perceptual data and to the acoustic measures of children between the ages of 3 and 9. The results showed that 84.5% of voices were classified as having a slight deviation, 2.8% as having a moderate deviation, and none as having a severe vocal deviation. As to auditory-perceptual parameters, most children presented a slight vocal deviation in the instability (47.88%), roughness (45.07%), and strain (40.84%) parameters.

Roughness and breathiness were associated with higher shimmer and lower GNE values[25]. That study also found that children with strained phonation obtained higher f0 values[25]. The physiological justification for this finding is that in such cases there in an increase in the longitudinal strain of vocal folds and the subglottic pressure, which in turn increase f0[25].

In the acoustic analysis of sound signal, the APQ, PPQ and NHN showed higher values among dysphonic children[1,19]. The mean f0 values are 230 Hz for dysphonic children and 245 Hz for children with normal voices. The study found a significant lower f0 value among the children with voice alterations[1,19].

The literature shows that the size of vocal nodules in children affects pitch perception, i.e., the larger the lesion, the more severe the pitch[23].

Two studies[26,27] associated the degree of dysphonic alteration with prematurity in dysphonic children. The findings indicate that children with extreme prematurity have more altered acoustic and auditory-perceptual analyses when compared to children born at full term[26]. Premature children with prolonged intubation periods obtained scores that indicate a negative impact on the quality of their voices[27].

Three articles compared vocal quality to chronic nasal obstruction in healthy children[1,28,29].

The vocal quality of children with superior airway obstruction have an insufficient nasal resonance, lower pitch and compressed voice. The acoustic assessment showed that f0 is lower among the groups with chronic nasal obstruction, and the jitter, shimmer and NHN measures proved better among the group without nasal obstructions[1,28,29].

The literature[1,20,30,31] concludes that dysphonic voice in childhood is characterized by a breathy, rough voice, ranging from a mild to a moderate degree. These auditory-perceptual measures are reflected in acoustic voice measures with a higher frequency periodicity (jitter and PPQ), intensity periodicity (shimmer and APQ) and higher noise measures (NHN). The f0 among this population is more severe, and is correlated with a pitch that is also severe. These findings suggest that both types of vocal quality assessment, auditory-perceptual and acoustic, are appropriate to pediatric vocal clinical practice, as they represent the voice of dysphonic children.

One only article analyzed the occurrence of two types of MPT (reduced, normal or increased) in children with nodules and cyst per gender[26]. Among the girls, the MPT were considered reduced. Among the boys with mass lesions, 50% showed MPTs considered normal, and 50% had reduced MPTs for sustained vowels[32].

We may conclude that dysphonia in childhood leads to a decrease in MPT values, mainly among male children. Further research into MPT values in dysphonic children is important to understand how gender impacts these values.

2. Vocal fold lesions

The prevalence of vocal fold lesions among the pediatric population with dysphonia was the object of study of 15 publications (44.1%). These studies indicated that nodules are the main cause of voice alterations in children; however, the prevalence of these lesions in children with vocal complaints varied from 12% to 94%[21,33,41].

Voice alterations were present in 67.6% of abuse victims treated at a health center[38]. The number of voice alterations found was larger than that found in the general population[38].

These studies concluded that in approximately 50% of children the presence of vocal nodules is associated with vocal abuse[36,39,40,41], in addition to causes such as nasal symptoms, pharyngeal--laryngeal reflux, and auditory alterations. Following nodules, epidermoid cysts and polyps were the most prevalent lesions, at 9.9% and 19%[23-37], respectively. The presence of epidermoid cysts is closely associated with congenital dysphonias, present in 7% of cases[35]. One study that analyzed approximately 839,000 children treated in a specialized health center in 2012 found that 1.4% reported some voice problem. Overall, 53.5% were diagnosed, with laryngitis being the most common diagnosis (16.6%), followed by allergies (10.4%)[4].

Two studies[35,37] broke down the sample by age brackets, and the results showed that, among children younger than 6 years old, the main cause of voice alterations is the presence of minimal structural alterations (MSA). The most prevalent MSA among children is the epidermoid vocal cyst[32-37]. An integrative review of the literature did not establish a behavioral profile among dysphonic children, nor did it find a correlation between child dysphonia and inappropriate vocal behavior[43]. Only among the group of children over 6 years old was there an association between dysphonia and vocal abuse[36], which is one of the triggers of lesions caused by vocal trauma, and, more specifically, of vocal nodules[36-41].

The literature[35] suggests that cysts are the most prevalent vocal fold lesions in children of up to 6 years of age, whereas among older children nodules become the most common type of lesion, due to behavioral factors. The high variability of the prevalence results found in the literature[18,26,27] (from 24% to 94%) may be explained by the difficulty in performing laryngeal videostroboscopies in children[18], who are often intolerant to this procedure, while most professionals do not specialize in pediatric laryngology. Another reason is the fact that most of the research used convenience samples, with little external validity.

It bears stressing that the production of studies investigating childhood dysphonia has grown over the past 10 years.

Conclusion

The review's findings show that the vocal quality of children without voice alterations is characterized by fundamental frequency values that decrease as age increases, with differences between the sexes and the speech tasks. The maximum phonation time also increases with age. Studies suggest that the vocal quality characteristic of dysphonic children is breathy and rough, with a mild

to moderate degree of alteration. Among dysphonic children, the voice acoustic measures and the maximum phonation time values are altered, and the fundamental frequency is lower. The results also indicate that dysphonia produces a negative impact on the children's quality of life.

Cysts are the most prevalent vocal fold lesion up to 6 years of age, followed by vocal nodules in older children, due to behavioral factors.

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