Literature Review

https://doi.org/10.1590/2317-6431-2023-2791en

Audiology Communication Research
ISSN 2317-6431

# Parameters and types of dysarthria assessment in amyotrophic lateral sclerosis

## Parâmetros e tipos de avaliação da disartria na esclerose lateral amiotrófica

*Luzimara Gláucia Oliveira Rodrigues*[1], *Ivonaldo Leidson Barbosa Lima*[2], *Mário Emílio Teixeira Dourado Júnior*[1,3], *Maria de Jesus Gonçalves*[2]

## ABSTRACT

**Purpose:** to identify studies regarding the parameters and types of assessment used to evaluate dysarthria in amyotrophic lateral sclerosis (ALS). **Research strategy:** an integrative literature review study was conducted on the LILACS, SciELO, PubMed, Web of Science, CINAHL, Scopus, and Cochrane databases using the descriptors "Assessment AND Dysarthria AND Amyotrophic Lateral Sclerosis" in both Portuguese and English. **Selection criteria:** the inclusion criteria consisted of articles that addressed studies on dysarthria assessment in ALS, written in English, Spanish, and Portuguese, which should be available in full, and published from 2015 to 2022. **Results:** out of the total of 38 studies, only 3 used a single type of dysarthria assessment. Most studies employed more than one type of assessment, ranging from 2 to 4 types. Three assessment types were predominantly used to assess the degree of speech intelligibility: auditoryperceptual assessment (31 studies), acoustic assessment (18 studies), and movement assessment (27 studies). **Conclusion:** dysarthria assessment in ALS is conducted through various procedures and with multiple analysis parameters, notably through auditory-perceptual and movement assessments.

**Keywords:** Amyotrophic lateral sclerosis; Assessment; Dysarthria; Speech intelligibility; Speech production measurement; Speech acoustics

## RESUMO

**Objetivo:** identificar estudos a respeito dos parâmetros e dos tipos de avaliação utilizados para avaliar a disartria na esclerose lateral amiotrófica (ELA). **Estratégia de pesquisa:** estudo de revisão integrativa da literatura realizada nas bases de dados LILACS, SciELO, PubMed, Web of Science, CINAHL, Scopus e Cochrane, por meios dos descritores, em português e em inglês, "Avaliação AND Disartria AND Esclerose Lateral Amiotrófica". **Critérios de seleção:** os critérios de inclusão foram: artigos que abordavam estudos sobre avaliação da disartria na ELA, nas línguas inglesa, espanhola e portuguesa, disponíveis na íntegra, no período de 2015 a 2022. **Resultados:** do total de 38 estudos, apenas 3 usaram um único tipo de avaliação da disartria. A maior parte dos estudos utilizou mais de um tipo de avaliação variando de 2 a 4. Foram 3 os tipos de avaliação mais utilizados, com o intuito de avaliar o grau de inteligibilidade de fala: avaliação perceptivo-auditiva (31 estudos), avaliação acústica (18 estudos) e avaliação do movimento (27 estudos). **Conclusão:** a avaliação da disartria na ELA é realizada por diferentes procedimentos e com vários parâmetros de análise, em especial pela avaliação perceptivo-auditiva e do movimento.

**Palavras-chave:** Esclerose lateral amiotrófica; Avaliação; Disartria; Inteligibilidade da fala; Medida da produção da fala; Acústica da fala

Study carried out at Departamento de Fonoaudiologia, Universidade Federal do Rio Grande do Norte – UFRN – Natal (RN), Brazil.
[1]Hospital Universitário Onofre Lopes – HUOL – Natal (RN), Brasil.
[2]Departamento de Fonoaudiologia, Universidade Federal do Rio Grande do Norte – UFRN – Natal (RN), Brasil.
[3]Departamento de Medicina Integrada, Universidade Federal do Rio Grande do Norte – UFRN – Natal (RN), Brasil.
**Conflict of interests:** No.
**Authors' contribution:** LGOR was responsible for data collection and analysis and article writing; ILBL and METDJ conducted data analysis and article review; MJG was responsible for the work guidance.
**Funding:** None.
**Corresponding author:** Luzimara Gláucia Oliveira Rodrigues. E-mail: luziglaucia@gmail.com
**Received:** April 06, 2023; **Accepted:** July 02, 2023

## INTRODUCTION

Amyotrophic Lateral Sclerosis (ALS) is a degenerative neuromuscular disease that affects upper and/or lower motor neurons. Considered as a rare disease, which affects two in every 100,000 people annually, it has a higher prevalence in men, with a ratio of 2:1, and the average age of onset is 57 years[1-3].

Due to the neuromuscular disorder, patients with ALS experience multidimensional declines, including alterations in speech, which are typically characterized by slowness, weakness, articulatory imprecision, and incoordination of the stomatognathic system[4]. Thus, communication through speech is compromised, resulting in dysarthria, which is defined as a disorder that affects the motor foundations of speech: respiration, phonation, resonance, articulation, and prosody[5].

Dysarthria can be present in various diseases and occurs due to lesions in the central or peripheral nervous system[6]. It is classified as: flaccid (associated with lower motor neuron impairment), spastic (linked to upper motor neuron lesions), ataxic (caused by cerebellar dysfunction), hypokinetic (related to extrapyramidal system disorder), and mixed (associated with damage in more than one area, resulting in at least two characteristics among the aforementioned)[7].

In ALS, dysarthria can manifest with either spastic or flaccid characteristics, and patients typically have articulation deficiencies, slow and laborious speech, imprecise consonantal production, hypernasality, and harshness[8]. Nonetheless, whether it's spastic or flaccid dysarthria, patients with ALS presenting such symptoms experience significant communication impairment[9].

Due to these communication impacts, it's important to focus on speech intelligibility — the ease with which a listener can understand their interlocutor's speech — by conducting regular assessments and suggesting interventions to prevent communicative isolation, including with family members and caregivers[10].

ALS currently lacks a cure, and its diagnosis is gradual, taking around 12 months to confirm, which is due to the absence of a marker that could indicate an earlier diagnosis[1]. Only neurological exams and basic speech tests, such as speech rate and intelligibility, are not sensitive assessments to the symptoms in the early stages of the disease[11]. This is why some studies have been engaged in the search for this marker, with the aim of monitoring and making decisions for faster and more effective interventions[12].

This diagnostic delay can impair the patient's mobility, swallowing, speech, and communication, thereby affecting the overall quality of life and causing biopsychosocial consequences[13-15]. In this context, it's necessary to act with the support of a multidisciplinary team that collaborates in an interdisciplinary manner to maximize the patient's and their family's quality of life through guidance on appropriate care to manage the situation[9,16]. Concerning dysarthria, the speech-language pathologist is responsible to detect, assess, and act based on the pillars of scientific evidence, promptly and effectively, thus preventing the loss of the patient's communication autonomy[17].

Therefore, considering the specific characteristics of ALS and its negative impact on speech function, resulting in communication deficits and diminished quality of life for affected individuals, the significance of conducting a study that synthesizes dysarthria assessment parameters and types is justified, which can be a valuable resource for guiding interventions aimed at this population.

## PURPOSE

To identify studies regarding the parameters and types of assessment used to evaluate dysarthria in ALS.

## RESEARCH STRATEGY

This is an integrative literature review study, which is a relevant tool in the field of health as it synthesizes available research on a specific topic and guides practices based on scientific knowledge[18]. In order to conduct this review, the researchers sought articles that addressed the following question: "What are the types of assessment and parameters used to evaluate dysarthria resulting from ALS?" To achieve this, the following steps were carried out: preparation of the guiding question, definition of descriptors, selection of inclusion and exclusion criteria for articles, article collection, application of eligibility criteria, review of titles and abstracts, and full article reading.

The consulted databases included: LILACS, SciELO, PubMed, Web of Science, CINAHL, Scopus and Cochrane; using the descriptors: "*Evaluation* AND *Dysarthria* AND *Amyotrophic Lateral Sclerosis*", "*Assessment* AND *Dysarthria* AND *Amyotrophic Lateral Sclerosis*", "*Avaliação* AND *Disartria* AND *Esclerose Lateral Amiotrófica*", tailored according to the research question.

## SELECTION CRITERIA

The search included scientific articles published in English, Portuguese, and Spanish between 2015 and 2022, provided they were freely available in the databases. In turn, the researchers excluded literature review articles of any kind, editorials, letters to the editor, and conference proceedings. Similarly, studies in which participants had dysarthria but not ALS were also excluded from the review.

## DATA ANALYSIS

After executing the search strategies and collecting studies to form the literature review, the articles were read in their entirety, and relevant data were extracted and organized in a digital spreadsheet. Then, the following data points were analyzed from the articles: purpose, sample characteristics, instruments used for dysarthria assessment, type of analysis and study design, as well as the primary findings.

## RESULTS

As the initial result of the search across all databases, a total of 973 articles were identified, as shown in Chart 1.

The initial article selection was based on reading the titles and abstracts. Following the inclusion criteria, 45 articles

**Chart 1.** Bumber of articles found in the databases based on the descriptors used in the literature search

| DESCRIPTORS | LILACS | SciELO | PubMED | Web of Science | CINAHL | Scopus | Cochrane |
|---|---|---|---|---|---|---|---|
| Evaluation AND Dysarthria AND Amyotrophic Lateral Sclerosis | 1 | 1 | 456 | 13 | 14 | 2 | 0 |
| Assessment AND Dysarthria AND Amyotrophic Lateral Sclerosis | 0 | 1 | 441 | 32 | 10 | 1 | 0 |
| Avaliação AND Disartria AND Esclerose Lateral Amiotrófica | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **Total = (973)** | **1** | **3** | **897** | **45** | **24** | **3** | **0** |

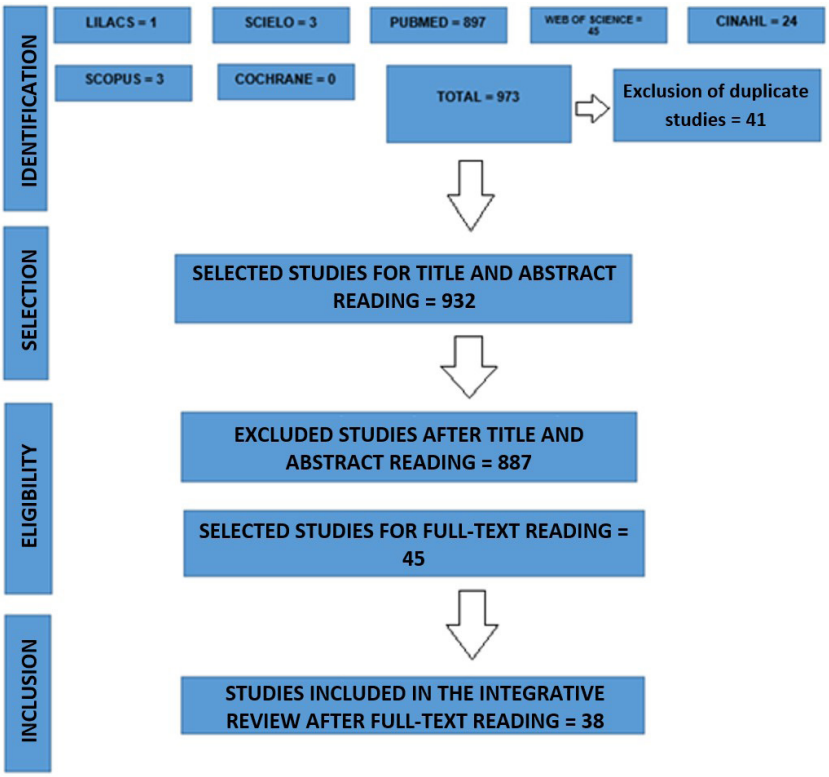


**Figure 1.** Flowchart for the selection of articles included in an integrative literature review on the types of assessment and instruments used to evaluate dysarthria resulting from amyotrophic lateral sclerosis

were chosen for full-text reading. After the thorough reading, 38 articles remained that aligned with the established scope of the study, as shown in the flowchart presented in Figure 1.

Among the studies found, there were only 2 from national literature, accounting for 5.2% of the sample, while the other 36 (94.7%) were from international literature. Specifically, 23 (60.5%) were from the United States (US), 3 (7.8%) from Canada, 2 (5.2%) from Finland, 1 (2.6%) from Italy, 1 (2.6%) from Poland, 1 from Geneva (2.6%), and 5 conducted jointly with the US and Canada (13.1%).

Regarding the research approaches, out of the 38 selected publications, 2 were quali-quantitative[19,20], while all others were quantitative. The statistical methods used varied across studies, encompassing both descriptive and inferential statistical analyses.

The total sample size across studies was 1619 participants, ranging from 10 to 147, with an average of 41.02 participants per study. The mean age of the study groups was 60 years, with 2 articles using age ranges instead of mean age[20,21]. Concerning gender distribution, there was a predominance of male participants, totaling 690, compared to 438 females. However, one study did not specify age or gender[22].

Regarding the study type, there were 13 longitudinal studies, 24 cross-sectional, and 1 cross-sectional study with a subset of longitudinal data[23].

In assessing dysarthria in ALS, three predominant evaluation methods were employed in the researched studies: auditory-perceptual assessment (31 studies), acoustic assessment (18 studies), and movement assessment (27 studies), all aimed to evaluate the degree of speech intelligibility (Chart 2). Among the 38 studies found in the databases, all utilized multiple evaluation types, ranging from 2 to 4 types.

The studies found in the databases that employed auditory-perceptual analysis obtained their results through measures of speech intelligibility, which are deemed particularly important in the differential diagnosis and quantification of dysarthria[26,42].

**Chart 2.** Analysis of articles used in the review

| Studies analyzed in review | | |
|---|---|---|
| **Assessment of dysarthria in amyotrophic lateral sclerosis** | | |
| Makkonen et al.[19] | Rong & Green[24] | Wang et al.[25] |
| Chiaramonte et al.[20] | Makkonen et al.[26] | Rong et al.[21] |
| Berry et al.[27] | Pawlukowska et al.[28] | Yunusova et al.[29] |
| Allison et al.[30] | Lee et al.[31] | Rong et al.[32] |
| Kuruvilla-Dugdale & Chuquilin-Arista[33] | Rong[34] | Leite & Constantini[35] |
| Green et al.[36] | Lee et al.[37] | Leite et al.[38] |
| Rong et al.[39] | Eshghi et al.[40] | Tanchip et al.[41] |
| Kuruvilla-Dugdale et al.[42] | Shellikeri et al.[23] | Shellikeri et al.[43] |
| Lee et al.[44] | Searl et al.[45] | Lancheros et al.[46] |
| Stipancic et al.[22] | Bandini et al.[47] | Stipancic et al.[48] |
| Lee & Bell[49] | Allison et al.[50] | Gutz et al.[51] |
| Lee et al.[52] | Kuruvilla-Dugdale & Mefferd[53] | Eshghi et al.[54] |
| | Wang et al.[55] | Kim et al.[56] |
| **Variables obtained in the studies** | | |
| **Longitudinal** | **Cross-sectional** | |
| Makkonen et al.[19] | Allison et al.[30] | Eshghi et al.[40] |
| Chiaramonte et al.[20] | Kuruvilla-Dugdale & Chuquilin-Arista[33] | Shellikeri et al.[23] |
| Berry et al.[27] | Green et al.[36] | Searl et al.[45] |
| Rong et al.[39] | Kuruvilla-Dugdale et al.[42] | Allison et al.[50] |
| Stipancic et al.[22] | Lee et al.[44] | Kuruvilla-Dugdale & Mefferd[53] |
| Shellikeri et al.[23] | Lee & Bell[49] | Yunusova et al.[29] |
| Bandini et al.[47] | Lee et al.[52] | Leite & Constantini[35] |
| Wang et al.[55] | Rong & Green[24] | Leite et al.[38] |
| Wang et al.[25] | Makkonen et al.[26] | Shellikeri et al.[43] |
| Rong et al.[21] | Pawlukowska et al.[28] | Lancheros et al.[46] |
| Rong et al.[32] | Lee et al.[31] | Eshghi et al.[54] |
| Tanchip et al.[41] | Rong[34] | Kim et al.[56] |
| Stipancic et al.[48] | Lee et al.[37] | |
| Gutz et al.[51] | | |
| **Auditory-perceptual Analysis** | **Acoustic Assessment** | **Movement Assessment** |
| Makkonen et al.[19] | Chiaramonte et al.[20] | Makkonen et al.[19] |
| Chiaramonte et al.[20] | Green et al.[36] | Chiaramonte et al.[20] |
| Berry et al.[27] | Rong et al.[39] | Kuruvilla-Dugdale & Chuquilin-Arista[33] |
| Allison et al.[30] | Lee et al.[44] | Rong et al.[39] |
| Green et al.[36] | Lee et al.[31] | Lee et al.[44] |
| Rong et al.[39] | Rong[34] | Lee & Bell[49] |
| Kuruvilla-Dugdale et al.[42] | Searl et al.[45] | Lee et al.[52] |
| Lee et al.[44] | Bandini et al.[47] | Rong & Green[24] |
| Stipancic et al.[22] | Allison et al.[50] | Makkonen et al.[26] |
| Lee & Bell[49] | Kuruvilla-Dugdale & Mefferd[53] | Pawlukowska et al.[28] |
| Lee et al.[52] | Wang et al.[55] | Lee et al.[31] |
| Makkonen et al.[26] | Wang et al.[25] | Rong [34] |
| Pawlukowska et al.[28] | Rong et al.[32] | Lee et al.[37] |
| Eshghi et al.[40] | Tanchip et al.[41] | Eshghi et al.[40] |
| Shellikeri et al.[23] | Shellikeri et al.[43] | Shellikeri et al.[23] |
| Bandini et al.[47] | Lancheros et al.[46] | Searl et al.[45] |
| Allison et al.[50] | Gutz et al.[51] | Bandini et al.[47] |
| Kuruvilla-Dugdale & Mefferd[53] | Eshghi et al.[54] | Allison et al.[50] |
| Wang et al.[55] | | Kuruvilla-Dugdale & Mefferd[53] |
| Wang et al.[25] | | Wang et al.[55] |
| Rong et al.[21] | | Wang et al.[25] |
| Yunusova et al.[29] | | Rong et al.[21] |
| Rong et al.[32] | | Rong et al.[32] |
| Leite & Constantini[35] | | Tanchip et al.[41] |
| Leite et al.[38] | | Shellikeri et al.[43] |
| Tanchip et al.[41] | | Lancheros et al.[46] |
| Shellikeri et al.[43] | | Kim et al.[56] |
| Lancheros et al.[46] | | |
| Stipancic et al.[48] | | |
| Gutz et al.[51] | | |
| Eshghi et al.[54] | | |

The analysis of speech intelligibility was frequently reported in the articles, as it constitutes a measure of speech perception by the listener. This measure is calculated by determining the percentage of words transcribed correctly out of the total number of words produced[42].

The speech rate was one of the measures used to assess speech intelligibility, examining the quantity of words spoken per minute. The reference value is 150 words per minute, and when lowered, it indicates bulbar compromise and speech deterioration[22,50,53,55].

Sentence length was another measure employed to evaluate speech intelligibility[30]. This assessment involves reading sentences in increasing order of length (from 5 to 15 words), allowing for the calculation of the percentage of intelligibility for each sentence[30,46].

Speech pause analysis was also one of the valuable measures to describe an individual's speech performance, as it provides important insights into the onset of bulbar impairment and disease progression[27,29,30,36,50].

A significant number of studies utilized acoustic analysis for dysarthria assessment in ALS[20,25,36,39,41,43-47,50,53,55]. Acoustic analysis is an objective method that, through signal processing and algorithms, can capture the waveform's contour, disturbance measures like jitter and shimmer, harmonics-to-noise ratio, as well as analyze the fundamental frequency. This allows for comprehensive descriptions of both normal and pathological voices[21,32,39,55].

In addition to the described parameters, acoustic analysis in the assessment of dysarthria in ALS facilitated the description of voice onset time, vowel formants, fundamental frequency, and cycle-to-cycle temporal variability[31,32,44,53].

One potential method for motion analysis is through articulography, in which orofacial movements are recorded using a 3D electromagnetic articulograph[24,33,39,44,49,52]. Motion capture sensors are placed strategically on regions like lips, tongue, and jaw, often with one sensor affixed to the forehead to establish a coordinate system and express the movement of each of the other sensors[24,33,39,44,49,52].

For motion analysis, one of the measures used was the rate of articulatory movements of the tongue, lower lip, and jaw[33,47,49,52]. Another measure was diadochokinesis, which assesses motor planning in speech, detecting even mild oromotor deficits resulting from bulbar dysfunction[34,39,41,43,50]. This is performed by uttering the syllables /pa/, /ta/, /ka/[34,39]. The Alternating Motion Rate (AMR) was also employed in the studies[21,32,40]. In this procedure the patient produces a syllable as quickly as possible in a single breath[21,32,40]. Figure 2 summarizes the key measures utilized in dysarthria assessment in ALS, as discussed in the studies of this review.

In addition to the aforementioned assessments, the studies used the Amyotrophic Lateral Sclerosis Functional Rating Scale – Revised (ALSFRS-R), which was correlated with the results of perceptual-auditory, movement, and acoustic analyses[21-23,27,38-40,47,49,50,52]. The ALSFRS-R is a questionnaire consisting of 12 questions that encompass the bulbar domain, motor coordination of minor and major muscles, and respiratory function[21-23,27,38-40,47,49,50,52].

Studies that analyzed the rate of articulatory movements of the tongue, lower lip, and jaw concluded that, when the rate of articulatory movement and tongue articulatory space decrease in individuals with severe dysarthria, the lower lip and jaw increase their movements, which is due to an attempt of the jaw to compensate for the reduced tongue movement in order to maintain intelligible speech[33,47,49,52,53].

Diadochokinesis proved to be a sensitive indicator of early bulbar decline, and the alternating motion rate enables a multifaceted assessment of motor capacity, involving the neuromotor system in spatial and temporal domains[34,39,41,43,50]. Patients had reduced ability for articulatory adjustments due to underlying neurological deficits[34,39,41,43,50].

Parameters of intelligibility and speech rate are crucial in determining the extent of speech impairment. Quantitative measurements of speech subsystems showed that articulatory and phonatory dysfunction were affected prior to the presence of speech intelligibility deficits and substantial reduction in speech rate[26,29,31,39,42,44,55]. A decrease in speech rate to 120 words per minute indicates the onset of decline in oral communication intelligibility[48].

Articulatory deficits, including reduced lip and jaw movement speed and diminished diadochokinesis rate, along with phonatory deficits and a narrowed range of fundamental frequency, served as sensitive indicators of early bulbar decline[24,28,33,34,37,39,40,47,49,52].

Studies further demonstrated that sentence length had an impact, since speech intelligibility decreased significantly in

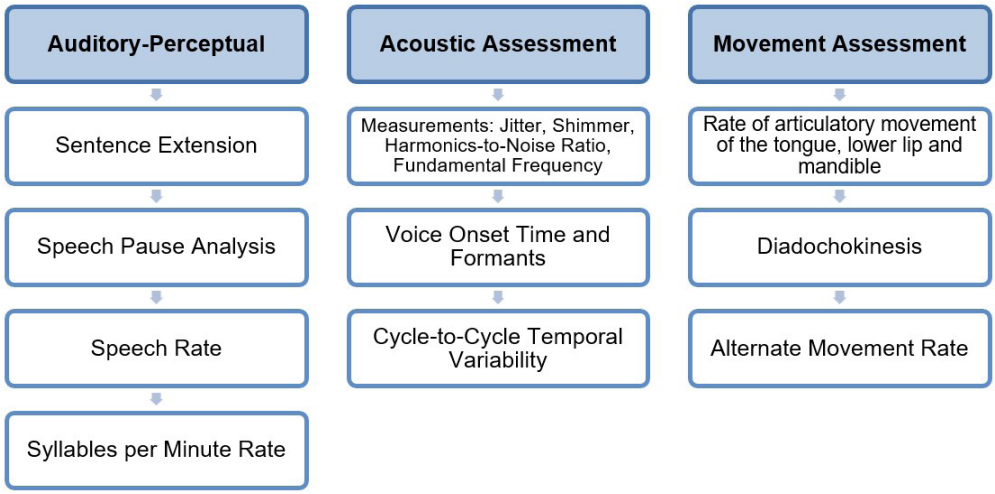


**Figure 2.** Demonstrative scheme of key measures used in dysarthria assessment in amyotrophic lateral sclerosis

longer sentences for speakers with more severe dysarthria symptoms[22,30,46]. On the other hand, speakers with mild to moderate dysarthria showed notable declines in speech rate and speech pause frequency[27,29,30,36,50].

Studies employing automated programs to analyze algorithmically estimated speech rate and pause patterns detected that as the degree of dysarthria advances, the speaker makes more pronounced pauses, which directly affects speech intelligibility[29,36,41,56].

In turn, the acoustic assessment found that numerous changes in the evaluated parameters facilitated the identification and monitoring of dysarthria progression in ALS[34,43,53,54].

Finally, more diagnostically accurate outcomes emerged when temporal characteristics of acoustic analysis (cycle-to-cycle temporal variability) were correlated with movement analysis (alternating motion rate and movement frequency)[34,53]. Among all acoustic and kinematic diadochokinesis measures, the highest diagnostic accuracy was found in the cycle-to-cycle temporal variability, with a sensitivity of 80% and specificity of 94%, in distinguishing individuals with ALS from healthy control individuals. This suggests that deficits in temporal control could serve as subclinical early bulbar signs in ALS[34].

## DISCUSSION

The evaluation process in diagnosing dysarthria resulting from ALS is of utmost importance, as it initiates possible interventions and disease progression monitoring based on the results. Hence, this study aimed to identify the types of assessment and parameters used through an integrative review.

The majority of the studies were of a quantitative nature. Objective measures prevailed within the assessment types used, which is in line with the literature, since quantitative analysis aims to quantify and measure events in an objective and precise manner[57].

It should be noted that a significant number of studies had a limited number of participants, ranging from 10 to 147 individuals. This may be attributed to the characteristics of ALS, as patients face challenges in participating in research endeavors due to their significant vulnerability. As reported by a study[17], there is also a limited survival time that can interfere with participation.

The average age of participants was 60 years, which is also in line with the literature, indicating that the age of diagnosis and first symptoms falls within the range of 58 to 60 years[58,59]. Regarding gender, males were more affected (56.4%), in line with findings from other studies[1].

The research identified that auditory-perceptual assessment, acoustic assessment, and movement assessment, all aimed at evaluating the degree of speech intelligibility, were the main types of evaluation. These measures, when correlated among themselves or with other instruments, provide relevant information regarding the presence or absence of dysarthria in ALS. Such findings are also reported in the literature of the field. Authors[60] report that a speech assessment comprises motor speech evaluation, speech subsystem screening, auditory-perceptual assessment, and intelligibility assessment, and that many of these procedures overlap, as dysarthria in ALS affects all speech subsystems.

Intelligibility and speech rate were evaluated in the auditory-perceptual analysis because they are fundamental measures for assessing dysarthria in ALS. Speech intelligibility is a widely used clinical measure as it demonstrates speech functionality or limitations and serves to document intervention efficacy[61].

Speech rate is directly related to intelligibility, declining before it; it decreases linearly with disease progression. This is due to a motor compensation that ALS patients enact to maintain intelligible speech[62]. Since reduced intelligibility and speech rate are nearly universal consequences of dysarthria, particularly in ALS, it is imperative for speech-language pathologists to have tools available to adequately evaluate these features[60].

Sentence length was also employed to assess the intelligibility of speech in patients with ALS. The longer the sentence, the more unintelligible the speech becomes, as the patient needs to make more motor adjustments and compensations to maintain intelligibility, and this leads to longer pauses during speech, reducing speech rate and articulation precision[30].

The analysis of speech pauses proved to be a useful measure to describe individual speech performance. Changes in this parameter in ALS can provide important information for diagnosis, such as the onset of bulbar impairment, since uncreased speech pauses may be an indicator of motor base compromise[63]. The correlation of speech pauses with intelligibility and speech rate is considered helpful in detecting changes associated with bulbar ALS[64].

Acoustic analysis is another method that provides subtle information through signal processing and algorithms. It enabled identification and monitoring of dysarthria evolution in ALS. It aids in understanding both normal and pathological voices, providing objective evidence for voice assessment as well as tracking progression and treatment effectiveness[65,66]. This method also aids in quantifying data and describing correlations between perceptual judgments of vocal quality, type of dysarthria, and speech intelligibility[67,68].

The analysis of studies also showed that fundamental frequency in ALS patients can either increase or decrease; similar evidence was cited in a study[69].

Movement analysis was evaluated through electromagnetic articulography, which is a tool that shows articulator movement patterns and speed, particularly the speed pattern of tongue movement. Authors[11] report that the tongue movement pattern can be a relevant parameter for early detection of bulbar impairment. While these patterns convey information about the severity of dysarthria, the disadvantage of articulography lies in the substantial investment required to acquire an electromagnetic articulograph[70].

Movement assessment through diadochokinesis also reveals neuromuscular integrity. This option has benefits, as it does not involve costs with devices and does not require the patient to have a cognition without any alteration[21].

Finally, the Amyotrophic Lateral Sclerosis Functional Rating Scale – Revised (ALSFRS-R) is a scale widely used in the assessment of patients with ALS to monitor the evolution of symptoms and possible limitations in carrying out routine activities[71]. The scale was used in the studies of this research[71] to establish correlations with the dysarthria assessment measures and the correlation was positive.

In this sense, the assessment of dysarthria in ALS requires the use of different types of assessment and needs to be performed by obtaining measurements of various parameters. The involvement of speech-language pathologists is essential in order to manage the assessment and care provided in relation to speech, since dysarthria in ALS causes significant declines

with devastating implications for the patient. In addition, the speech-language evaluation of dysarthria can be a criterion for the differential diagnosis. According to the results, there was a limited number of national productions, which makes it difficult to obtain information about how evaluations are being carried out in Brazil.

## CONCLUSION

The assessment of dysarthria in ALS is performed using various parameters and different assessment procedures. This variability results from the need to analyze the functioning of all speech motor bases. The auditory-perceptual analysis is the most used in the evaluation. The contribution of objective measures, such as acoustic analysis and motion analysis, is emphasized in establishing assessment criteria and monitoring dysarthria in ALS.

## REFERENCES


1. Brown RH, Al-Chalabi A. Amyotrophic lateral sclerosis. N Engl J Med. 2017;377(2):162-72. http://dx.doi.org/10.1056/NEJMra1603471. PMid:28700839.
2. van Es MA, Hardiman O, Chio A, Al-Chalabi A, Pasterkamp RJ, Veldink JH, et al. Amyotrophic lateral sclerosis. Lancet. 2017;390(10107):2084-98. http://dx.doi.org/10.1016/S0140-6736(17)31287-4. PMid:28552366.
3. Hardiman O, Al-Chalabi A, Chio A, Corr EM, Logroscino G, Robbert W. Amyotrophic lateral sclerosis. Nat Rev Dis Primers. 2017;3:1-18.
4. Pontes RT, Orsini M, Freitas MRG, Antonioli RS, Nascimento OJM. Alterações da fonação e deglutição na esclerose lateral amiotrófica: revisão de literatura. Rev Neurocienc. 2010;18(1):69-73. http://dx.doi.org/10.34024/rnc.2010.v18.8505.
5. Lamônia D. Comunicação alternativa: reflexões para o processo terapêutico de adultos com lesão cerebral. In: Deliberato D, Gonçalves M, Macedo E., editors. Comunicação alternativa: teoria, prática, tecnologias e pesquisa. São Paulo: Memnon Edições Científicas; 2009. p. 125-31.
6. Ortiz KZ. Distúrbios neurológicos adquiridos: fala e deglutição. Barueri: Manole; 2010.
7. Enderby P. Disorders of communication: dysarthria. Handb Clin Neurol. 2013;110:273-81. http://dx.doi.org/10.1016/B978-0-444-52901-5.00022-8. PMid:23312647.
8. Tomik B, Guiloff RJ. Dysarthria in amyotrophic lateral sclerosis: a review. Amyotroph Lateral Scler. 2010;11(1-2):4-15. http://dx.doi.org/10.3109/17482960802379004. PMid:20184513.
9. Silva LP, Gusmão CA, Pithon KR, Gomes TBP, Pinto EP Jr. Esclerose lateral amiotrófica: descrição de aspectos clínicos e funcionais de uma série de casos numa região de saúde do nordeste do Brasil. J Health Biol Sci. 2018;6(3):293-8. http://dx.doi.org/10.12662/2317-3076jhbs.v6i3.1811.p293-298.2018.
10. Barreto SS, Ortiz KZ. Medidas de inteligibilidade nos distúrbios da fala: revisão crítica da literatura. Pro Fono. 2008;20(3):201-6. http://dx.doi.org/10.1590/S0104-56872008000300011. PMid:18852969.
11. Green JR, Yunusova Y, Kuruvilla MS, Wang J, Pattee GL, Synhorst L, et al. Bulbar and speech motor assessment in ALS: challenges and future directions. Amyotroph Lateral Scler Frontotemporal Degener. 2013;14(7-8):494-500. http://dx.doi.org/10.3109/21678421.2013.817585. PMid:23898888.
12. Cavaco SG. Esclerose lateral amiotrófica: fisiopatologia e novas abordagens farmacológicas [dissertation]. Faro, Portugal: Faculdade de Ciências e Tecnologia, Universidade do Algarve; 2016.
13. Madureira CDPVG. Diagnóstico diferencial de esclerose lateral amiotrófica: a propósito de um caso clínico [dissertation]. Covilhã: Universidade da Beira Interior; 2012.
14. Chiaramonte R, Bonfiglio M. Acoustic analysis of voice in bulbar amyotrophic lateral sclerosis: a systematic review and metanalysis of studies. Logoped Phoniatr Vocol. 2020;45(4):151-63. http://dx.doi.org/10.1080/14015439.2019.1687748. PMid:31760837.
15. Siqueira SC, Vitorino PVO, Prudente COM, Santana TS, Melo GF. Qualidade de vida de pacientes com esclerose lateral amiotrófica. Rev Rene. 2017;18(1):139-46. http://dx.doi.org/10.15253/2175-6783.2017000100019.
16. Rooney J, Byrne S, Heverin M, Tobin K, Dick A, Donaghy C, et al. A multidisciplinary clinic approach improves survival in ALS: a comparative study of ALS in Ireland and Northern Ireland. J Neurol Neurosurg Psychiatry. 2015;86(5):496-501. http://dx.doi.org/10.1136/jnnp-2014-309601. PMid:25550416.
17. Leite L No, França MC Jr, Chun RYS. Esclerose lateral amiotrófica, disartria e alterações de linguagem: tipo de pesquisa e abordagens em diferentes áreas - revisão integrativa da literatura. Rev CEFAC. 2021;23(1):e8220. http://dx.doi.org/10.1590/1982-0216/20212318220.
18. Souza MT, Silva MD, Carvalho R. Revisão integrativa: o que é e como fazer. Einstein. 2010;8(1):102-6. http://dx.doi.org/10.1590/s1679-45082010rw1134. PMid:26761761.
19. Makkonen T, Korpijaakko-Huuhka AM, Ruottinen H, Puhto R, Hollo K, Ylinen A, et al. Oral motor functions, speech and communication before a definitive diagnosis of amyotrophic lateral sclerosis. J Commun Disord. 2016;61:97-105. http://dx.doi.org/10.1016/j.jcomdis.2016.04.002. PMid:27110704.
20. Chiaramonte R, Di Luciano C, Chiaramonte I, Serra A, Bonfiglio M. Multi-disciplinary clinical protocol for the diagnosis of bulbar amyotrophic lateral sclerosis. Acta Otorrinolaringol Esp. 2019 Jan-Feb;70(1):25-31. http://dx.doi.org/10.1016/j.otorri.2017.12.002. PMid:29699694.
21. Rong P, Yunusova Y, Richburg B, Green JR. Automatic extraction of abnormal lip movement features from the alternating motion rate task in amyotrophic lateral sclerosis. Int J Speech Lang Pathol. 2018;20(6):610-23. http://dx.doi.org/10.1080/17549507.2018.1485739. PMid:30253671.
22. Stipancic KL, Yunusova Y, Berry JD, Green JR. Minimally detectable change and minimal clinically important difference of a decline in sentence intelligibility and speaking rate for individuals with amyotrophic lateral sclerosis. J Speech Lang Hear Res. 2018 Nov;61(11):2757-71. http://dx.doi.org/10.1044/2018_JSLHR-S-17-0366. PMid:30383220.
23. Shellikeri S, Green JR, Kulkarni M, Rong P, Martino R, Zinman L, et al. Speech movement measures as markers of bulbar disease in amyotrophic lateral sclerosis. J Speech Lang Hear Res. 2016;59(5):887-99. http://dx.doi.org/10.1044/2016_JSLHR-S-15-0238. PMid:27679842.
24. Rong P, Green JR. Predicting speech intelligibility based on spatial tongue-jaw coupling in persons with amyotrophic lateral sclerosis: the impact of tongue weakness and jaw adaptation. J Speech Lang Hear Res. 2019;62(8S):3085-103. http://dx.doi.org/10.1044/2018_JSLHR-S-CSMC7-18-0116. PMid:31465706.
25. Wang J, Kothalkar PV, Kim M, Bandini A, Cao B, Yunusova Y, et al. Automatic prediction of intelligible speaking rate for individuals with

ALS from speech acoustic and articulatory samples. Int J Speech Lang Pathol. 2018;20(6):669-79. http://dx.doi.org/10.1080/17549507.2018.1508499. PMid:30409057.

26. Makkonen T, Ruottinen H, Puhto R, Helminen M, Palmio J. Speech deterioration in amyotrophic lateral sclerosis (ALS) after manifestation of bulbar symptoms. Int J Lang Commun Disord. 2018;53(2):385-92. http://dx.doi.org/10.1111/1460-6984.12357. PMid:29159848.

27. Berry JD, Paganoni S, Carlson K, Burke K, Weber H, Staples P, et al. Design and results of a smartphone-based digital phenotyping study to quantify ALS progression. Ann Clin Transl Neurol. 2019;6(5):873-81. http://dx.doi.org/10.1002/acn3.770. PMid:31139685.

28. Pawlukowska W, Baumert B, Gołąb-Janowska M, Meller A, Machowska-Sempruch K, Wełnicka A, et al. Comparative assessment and monitoring of deterioration of articulatory organs using subjective and objective tools among patients with amyotrophic lateral sclerosis. BMC Neurol. 2019;19(1):241. http://dx.doi.org/10.1186/s12883-019-1484-2. PMid:31629403.

29. Yunusova Y, Graham NL, Shellikeri S, Phuong K, Kulkarni M, Rochon E, et al. Profiling speech and pausing in Amyotrophic Lateral Sclerosis (ALS) and Frontotemporal Dementia (FTD). PLoS One. 2016;11(1):e0147573. http://dx.doi.org/10.1371/journal.pone.0147573. PMid:26789001.

30. Allison KM, Yunusova Y, Green JR. Shorter sentence length maximizes intelligibility and speech motor performance in persons with dysarthria due to amyotrophic lateral sclerosis. Am J Speech Lang Pathol. 2019;28(1):96-107. http://dx.doi.org/10.1044/2018_AJSLP-18-0049. PMid:31072158.

31. Lee J, Littlejohn MA, Simmons Z. Acoustic and tongue kinematic vowel space in speakers with and without dysarthria. Int J Speech Lang Pathol. 2017;19(2):195-204. http://dx.doi.org/10.1080/17549507.2016.1193899. PMid:27336197.

32. Rong P, Yunusova Y, Wang J, Zinman L, Pattee GL, Berry JD, et al. Predicting speech intelligibility decline in amyotrophic lateral sclerosis based on the deterioration of individual speech subsystems. PLoS One. 2016;11(5):e0154971. http://dx.doi.org/10.1371/journal.pone.0154971. PMid:27148967.

33. Kuruvilla-Dugdale M, Chuquilin-Arista M. An investigation of clear speech effects on articulatory kinematics in talkers with ALS. Clin Linguist Phon. 2017;31(10):725-42. http://dx.doi.org/10.1080/02699206.2017.1318173. PMid:28494172.

34. Rong P. Automated acoustic analysis of oral diadochokinesis to assess bulbar motor involvement in amyotrophic lateral sclerosis. J Speech Lang Hear Res. 2020;63(1):59-73. http://dx.doi.org/10.1044/2019_JSLHR-19-00178. PMid:31940257.

35. Leite L No, Constantini AC. Dysarthria and quality of life in patients with amyotrophic lateral sclerosis. Rev CEFAC. 2017;19(5):664-73. http://dx.doi.org/10.1590/1982-021620171954017.

36. Green JR, Allison KM, Cordella C, Richburg BD, Pattee GL, Berry JD, et al. Additional evidence for a therapeutic effect of dextromethorphan/quinidine on bulbar motor function in patients with amyotrophic lateral sclerosis: a quantitative speech analysis. Br J Clin Pharmacol. 2018;84(12):2849-56. http://dx.doi.org/10.1111/bcp.13745. PMid:30152872.

37. Lee J, Rodriguez E, Mefferd A. Direction-specific jaw dysfunction and its impact on tongue movement in individuals with dysarthria secondary to amyotrophic lateral sclerosis. J Speech Lang Hear Res. 2020 Feb;63(2):499-508. http://dx.doi.org/10.1044/2019_JSLHR-19-00174. PMid:32074462.

38. Leite L No, França MC Jr, Chun RYS. Inteligibilidade de fala em pessoas com Esclerose Lateral Amiotrófica (ELA). CoDAS. 2021;33(1):e20190214. http://dx.doi.org/10.1590/2317-1782/20202019214. PMid:33533830.

39. Rong P, Yunusova Y, Wang J, Green JR. Predicting early bulbar decline in amyotrophic lateral sclerosis: a speech subsystem approach. Behav Neurol. 2015;2015:183027. http://dx.doi.org/10.1155/2015/183027. PMid:26136624.

40. Eshghi M, Stipancic KL, Mefferd A, Rong P, Berry JD, Yunusova Y, et al. Assessing oromotor capacity in ALS: the effect of a fixed-target task on lip biomechanics. Front Neurol. 2019;10:1288. http://dx.doi.org/10.3389/fneur.2019.01288. PMid:31866935.

41. Tanchip C, Guarin DL, McKinlay S, Barnett C, Kalra S, Genge A, et al. Validating automatic diadochokinesis analysis methods across dysarthria severity and syllable task in amyotrophic lateral sclerosis. J Speech Lang Hear Res. 2022;65(3):940-53. http://dx.doi.org/10.1044/2021_JSLHR-21-00503. PMid:35171700.

42. Kuruvilla-Dugdale M, Custer C, Heidrick L, Barohn R, Govindarajan R. A phonetic complexity-based approach for intelligibility and articulatory precision testing: a preliminary study on talkers with amyotrophic lateral sclerosis. J Speech Lang Hear Res. 2018 Sep;61(9):2205-14. http://dx.doi.org/10.1044/2018_JSLHR-S-17-0462. PMid:30208408.

43. Shellikeri S, Marzouqah R, Brooks BR, Zinman L, Green JR, Yunusova Y. Psychometric properties of rapid word-based rate measures in the assessment of bulbar amyotrophic lateral sclerosis: comparisons with syllable-based rate tasks. J Speech Lang Hear Res. 2021;64(11):4178-91. http://dx.doi.org/10.1044/2021_JSLHR-21-00038. PMid:34699273.

44. Lee J, Dickey E, Simmons Z. Vowel-specific intelligibility and acoustic patterns in individuals with dysarthria secondary to amyotrophic lateral sclerosis. J Speech Lang Hear Res. 2019;62(1):34-59. http://dx.doi.org/10.1044/2018_JSLHR-S-17-0357. PMid:30950759.

45. Searl J, Knollhoff S, Barohn RJ. Lingual-alveolar contact pressure during speech in amyotrophic lateral sclerosis: preliminary findings. J Speech Lang Hear Res. 2017;60(4):810-25. http://dx.doi.org/10.1044/2016_JSLHR-S-16-0107. PMid:28335033.

46. Lancheros M, Pernon M, Laganaro M. Is there a continuum between speech and other oromotor tasks? Evidence from motor speech disorders. Aphasiology. 2023;37(5):715-34. http://dx.doi.org/10.1080/02687038.2022.2038367.

47. Bandini A, Green JR, Wang J, Campbell TF, Zinman L, Yunusova Y. Kinematic features of jaw and lips distinguish symptomatic from presymptomatic stages of bulbar decline in amyotrophic lateral sclerosis. J Speech Lang Hear Res. 2018;61(5):1118-29. http://dx.doi.org/10.1044/2018_JSLHR-S-17-0262. PMid:29800359.

48. Stipancic KL, Palmer KM, Rowe HP, Yunusova Y, Berry JD, Green JR. "You Say Severe, I Say Mild": toward an empirical classification of dysarthria severity. J Speech Lang Hear Res. 2021;64(12):4718-35. http://dx.doi.org/10.1044/2021_JSLHR-21-00197. PMid:34762814.

49. Lee J, Bell M. Articulatory range of movement in individuals with dysarthria secondary to amyotrophic lateral sclerosis. Am J Speech Lang Pathol. 2018;27(3):996-1009. http://dx.doi.org/10.1044/2018_AJSLP-17-0064. PMid:29800071.

50. Allison KM, Yunusova Y, Campbell TF, Wang J, Berry JD, Green JR. The diagnostic utility of patient-report and speech-language pathologists' ratings for detecting the early onset of bulbar symptoms due to ALS. Amyotroph Lateral Scler Frontotemporal Degener. 2017;18(5-6):358-66. http://dx.doi.org/10.1080/21678421.2017.1303515. PMid:28355886.

51. Gutz SE, Stipancic KL, Yunusova Y, Berry JD, Green JR. Validity of off-the-shelf automatic speech recognition for assessing speech intelligibility and speech severity in speakers with amyotrophic lateral sclerosis. J Speech Lang Hear Res. 2022;65(6):2128-43. http://dx.doi.org/10.1044/2022_JSLHR-21-00589. PMid:35623334.

52. Lee J, Bell M, Simmons Z. Articulatory kinematic characteristics across the dysarthria severity spectrum in individuals with amyotrophic lateral sclerosis. Am J Speech Lang Pathol. 2018;27(1):258-69. http://dx.doi.org/10.1044/2017_AJSLP-16-0230. PMid:29209698.

53. Kuruvilla-Dugdale M, Mefferd A. Spatiotemporal movement variability in ALS: speaking rate effects on tongue, lower lip, and jaw motor control. J Commun Disord. 2017;67:22-34. http://dx.doi.org/10.1016/j.jcomdis.2017.05.002. PMid:28528293.

54. Eshghi M, Connaghan KP, Gutz SE, Berry JD, Yunusova Y, Green JR. Co-occurrence of hypernasality and voice impairment in amyotrophic lateral sclerosis: acoustic quantification. J Speech Lang Hear Res. 2021;64(12):4772-83. http://dx.doi.org/10.1044/2021_JSLHR-21-00123. PMid:34714698.

55. Wang J, Kothalkar PV, Kim M, Yunusova Y, Campbell TF, Heitzman D, et al. Predicting intelligible speaking rate in individuals with amyotrophic lateral sclerosis from a small number of speech acoustic and articulatory samples. Workshop Speech Lang Process Assist Technol. 2016;2016:91-7. http://dx.doi.org/10.21437/SLPAT.2016-16. PMid:29423454.

56. Kim D, Kuruvilla-Dugdale M, de Riesthal M, Jones R, Bagnato F, Mefferd A. Articulatory correlates of stress pattern disturbances in talkers with dysarthria. J Speech Lang Hear Res. 2021 Jun;64(6S):2287-300. http://dx.doi.org/10.1044/2021_JSLHR-20-00299. PMid:33984259.

57. Proetti S. As pesquisas qualitativa e quantitativa como métodos de investigação científica: um estudo comparativo e objetivo. Rev Lumen. 2017;2(4):1-23.

58. Talbott EO, Malek AM, Lacomis D. The epidemiology of amyotrophic lateral sclerosis. Handb Clin Neurol. 2016;138:225-38. http://dx.doi.org/10.1016/B978-0-12-802973-2.00013-6. PMid:27637961.

59. Palermo S, Lima JMB, Alvarenga RP. Epidemiologia da esclerose lateral amiotrófica - Europa/América do Norte/América do Sul/Ásia. Discrepâncias e similaridades. Revisão sistemática da literatura. Rev Bras Neurol. 2009;45(2):5-10.

60. Spencer KA, Brown KA. Dysarthria following stroke. Semin Speech Lang. 2018;39(1):15-24. http://dx.doi.org/10.1055/s-0037-1608852. PMid:29359302.

61. Yorkston KM, Beukelman DR, Hakel M, Dorsey M. Speech intelligibility test for Windows. Lincoln: Communication Disorders Software; 2007.

62. Ball LJ, Beukelman DR, Pattee GL. Timing of speech deterioration in people with amyotrophic lateral sclerosis. Am J Speech Lang Pathol. 2002;10(4):231-5.

63. Connaghan KP, Green JR, Paganoni S, Chan J, Weber H, Collins E, et al. Use of Beiwe smartphone app to identify and track speech decline in amyotrophic lateral sclerosis. Proc Interspeech. 2019:4504-8. http://dx.doi.org/10.21437/Interspeech.2019-3126.

64. Barnett C, Green JR, Marzouqah R, Stipancic KL, Berry JD, Korngut L, et al. Reliability and validity of speech & pause measures during passage reading in ALS. Amyotroph Lateral Scler Frontotemporal Degener. 2020 Feb;21(1-2):42-50. http://dx.doi.org/10.1080/21678421.2019.1697888. PMid:32138555.

65. Shu M, Jiang JJ, Willey M. The effect of moving window on acoustic analysis. J Voice. 2016;30(1):5-9. http://dx.doi.org/10.1016/j.jvoice.2014.11.008. PMid:25998407.

66. Araújo SA, Grellet M, Pereira JC, Rosa MO. Normatização de medidas acústicas da voz normal. Rev Bras Otorrinolaringol. 2002;68(4):540-4. http://dx.doi.org/10.1590/S0034-72992002000400014.

67. Carrillo L, Ortiz KZ. Análise vocal (auditiva e acústica) nas disartrias. Pro Fono. 2007;19(4):381-6. http://dx.doi.org/10.1590/S0104-56872007000400010. PMid:18200388.

68. Mou Z, Chen Z, Yang J, Xu L. Acoustic properties of vowel production in Mandarin-speaking patients with post-stroke dysarthria. Sci Rep. 2018;8(1):14188. http://dx.doi.org/10.1038/s41598-018-32429-8. PMid:30242251.

69. Kent JF, Kent RD, Rosenbek JC, Weismer G, Martin R, Sufit R, et al. Quantitative description of the dysarthria in women with amyotrophic lateral sclerosis. J Speech Lang Hear Res. 1992;35:723-33. http://dx.doi.org/10.1044/jshr.3504.723.

70. Rong P, Green JR. Predicting speech intelligibility based on spatial tongue–jaw coupling in persons with amyotrophic lateral sclerosis: the impact of tongue weakness and jaw adaptation. J Speech Lang Hear Res. 2019 Aug;62(8S):3085-103. http://dx.doi.org/10.1044/2018_JSLHR-S-CSMC7-18-0116. PMid:31465706.

71. Guedes K, Pereira C, Pavan K, Valério BCO. Cross-cultural adaptation and validation of als Functional Rating Scale-Revised in Portuguese language. Arq Neuropsiquiatr. 2010;68(1):44-7. http://dx.doi.org/10.1590/S0004-282X2010000100010. PMid:20339651.