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QUALITY OF LIFE QUESTIONNAIRE AND FREQUENCY FOLLOWING RESPONSE IN TWO DYSARTHRIC SUBJECTS WITH NEURODEGENERATIVE DISEASE: A CASE STUDY

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

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Abstract

Background: Effective speech production involves a complex system that not only requires planning and motor execution in different speech subsystems, but also depends on the proper functioning of the auditory system. In cases of dysarthria, auditory electrophysiological assessment can be important, since it can help diagnose the underlying neurological disease. The objective of this pilot study was to assess the effectiveness of the frequency-following response (FFR) in monitoring the progress of speech therapy in cases of dysarthria due to neurodegenerative disease. It also sought to gauge changes in the patients' quality of life using a self-report questionnaire.

Case report: Two individuals with dysarthria were assessed by the FFR and by the questionnaire "Living with Dysarthria" while undergoing a speech therapy rehabilitation program aimed at improving their speech. It was found that the speech therapy brought benefits in terms of quality of life, in line with the FFR responses.

Conclusions: The FFR may be a promising approach to monitoring changes in the central auditory nervous system during speech therapy for dysarthria due to acquired neurodegenerative disease.

Keywords: electrophysiology • hearing • dysarthria • frequency following response • auditory evoked potential

KWESTIONARIUSZ JAKOŚCI ŻYCIA I ODPOWIEDZI PODĄŻAJĄCE ZA CZĘSTOTLIWOŚCIĄ U DWÓCH PACJENTÓW Z DYZARTRIĄ I CHOROBĄ NEURODEGENERACYJNĄ: ANALIZA PRZYPADKU

Streszczenie

Wprowadzenie: Do skutecznej produkcji mowy konieczne jest zaangażowanie złożonego systemu, który wymaga nie tylko planowania i wykonania motorycznego w różnych podsystemach mowy, lecz także zależy od prawidłowego funkcjonowania układu słuchowego. W przypadkach dyzartrii istotne może być przeprowadzenie elektrofizjologicznej oceny słuchu, która może wspomóc diagnostykę pierwotnego schorzenia neurologicznego. Celem tego badania pilotażowego była ocena skuteczności odpowiedzi podążających za częstotliwością (FFR) w monitorowaniu postępów terapii mowy w przypadkach dysartrii spowodowanej chorobą neurodegeneracyjną. Drugim celem była ocena zmiany jakości życia pacjentów za pomocą kwestionariusza samooceny.

Analiza przypadku: Dwóch pacjentów z dyzartrią zostało zbadanych z użyciem FFR oraz kwestionariusza „Życie z dyzartrią" („Living with Dysarthria") w trakcie programu rehabilitacji mowy. Wyniki wskazują, że terapia mowy przyniosła pozytywne rezultaty w odniesieniu do jakości życia pacjentów oraz wyników odpowiedzi FFR.

Wnioski: Rejestracja FFR może być obiecującą metodą monitorowania zmian w ośrodkowym układzie nerwowym podczas terapii mowy w związku z dyzartrią spowodowaną nabytą chorobą neurodegeneracyjną.

Słowa kluczowe: elektrofizjologia • słuch • dyzartria • odpowiedzi podążające za częstotliwością • słuchowe odpowiedzi wywołane

Introduction

Progressive neurological diseases, such as Parkinson's disease (PD), amyotrophic lateral sclerosis (ALS), and others have motivated much research because these neurodegenerative diseases severely affect quality of life [1]. About 70 to 90% of patients with progressive neurological diseases have speech and voice disorders, generally known as dysarthria [2,3]. Dysarthria results from a disturbance in the control of speech due to damage to the central or peripheral nervous system. Speech production is impaired due to paralysis, weakness, or uncoordination of the speech muscles which in turn affects one or several of the five components: breathing, phonation, resonance, articulation, and prosody [4,5].

To undertake a differential diagnosis of dysarthria and its impact on quality of life, a set of auditory-perceptual assessments or related self-assessments are needed. Determining what type of dysarthria is involved is important for identifying the underlying speech-language pathology and for choosing suitable rehabilitation and treatment targets [6].

Adequate speech production is important for maintaining quality of life. Speech is a complex system that requires not only motor planning and execution, but also depends on adequate auditory input [6]. This means that motor speech disorders such as dysarthria need to be treated according to basic learning principles. There is a hierarchy of speech motor activity [5], comprising a set of cognitive processes involving practice, training, and experience which result in a permanent change in motor behavior. This approach is related to the principles of neural plasticity, which include specificity, repetition, intensity, timing, salience, transference, and interference. Together, they aim to maximize new neural connections [7] and emphasize the importance of therapy, self-assessment, and monitoring so as to improve the quality of life of the dysarthric patient [8].

In this context, electrophysiological assessments in cases of dysarthria are important, and generally highlight the usefulness of monitoring in assessing people with neurological diseases [1]. Among the possible biomarkers, the frequency-following response (FFR) stands out, as it has the ability to assess neural response times and how sounds are coded in an objective way [9–11]. The FFR can be applied in patients with auditory processing disorders and specific language disorders; it is also well-suited to monitoring therapeutic interventions. This auditory evoked potential can be used to monitor changes in the central auditory nervous system (CANS) and be an objective measure of how therapy is progressing [10].

However, there is a scarcity of studies investigating the clinical applicability of the FFR in individuals with acquired neurodegenerative disease, particularly dysarthria. In this disease, the FFR can be used to monitor the progression of the pathology and track the interventions and responses. Thus, the objective of the present study was to verify the effectiveness of the FFR in monitoring speech therapy in two cases of dysarthria due to neurodegenerative disease; in parallel, we looked at changes in the patients' quality of life through use of a self-report questionnaire.

Case report

This is a descriptive, longitudinal, and qualitative pilot study approved by the research ethics committee of the Federal University of Santa Maria (nr 23081.019037/2017-19). Both participants signed a Free and Informed Consent Form. The norms and guidelines for research on human beings under Resolution 466/12 of the National Health Council were respected. The subjects underwent a diagnostic process for acquired neurological impairment associated with dysarthria. The diagnosis was part of a detailed study carried out by a multidisciplinary team consisting of a neurologist from the Neurology Sector of the Hospital Universitário de Santa Maria (HUSM) and a speech therapist specialising in dysarthria from the Speech Therapy Course of the Universidade Federal de Santa Maria (UFSM).

Initially, 11 subjects were recruited to the study, but 8 were excluded as they were unable to attend all speech-language rehabilitation sessions due to SARS-CoV-2 infection. One subject who had chronic tinnitus and alterations in the middle ear (curve B or C) was also excluded. Thus, the present study involved just two patients, namely, subject 1: a male, 71 years old, diagnosed with Parkinson's disease and hypokinetic dysarthria; and subject 2: a male, 58 years old, diagnosed with amyotrophic lateral sclerosis and mixed dysarthria (flaccid + spastic).

The two participants were evaluated in two stages: 1st stage (pre-intervention) and 2nd stage (post-intervention). The 1st stage involved the following procedures: initial interview, inspection of the external acoustic meatus, pure tone audiometry, logoaudiometry, immittanceometry, a self-assessment questionnaire ("Living with Dysarthria"), and electrophysiological assessment using the frequency following response (FFR). In the 2nd stage, following rehabilitation treatment, the "Living with Dysarthria" questionnaire was repeated as well as the FFR. Both patients did not have any other previous pathology or any type of previous intervention.

The evaluations were carried out blindly so that the evaluator was not informed of the stage of the participant. Each part of the study was performed by a different evaluator, arranged as follows. a) Audiological assessment (1st stage)

– researcher A who is a specialist in audiology; b) audiological reassessment (2nd stage) – researcher B who is also an audiology specialist; c) speech-language pathology assessment and self-assessment by “Living with Dysarthria” (1st stage) – researcher C who is a specialist in speech motor disorders; d) speech-language pathology assessment and “Living with Dysarthria” reassessment (2nd stage) – researcher D who is a specialist in speech motor disorders.

The “Living with Dysarthria” questionnaire was translated into Brazilian Portuguese and culturally adapted [12]. The purpose of the questionnaire was to verify how participants perceived themselves and their speech difficulties and how they adjusted to different situations. The questionnaire consisted of 50 statements divided into 10 different sections, and a total score was calculated by summing the scores of all statements in each section. The minimum possible score is 50 points, suggesting there is little impact of dysarthria on quality of life, and the maximum score is 300 points, which indicates a high impact of dysarthria on quality of life.

The audiological assessments were conducted as follows. a) Audiometric evaluation of air conduction thresholds at 0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz and bone conduction at 0.5, 1, 2, and 4 kHz. Auditory thresholds were considered normal up to 15 dB in air conduction and up to 20 dB in bone conduction according to the classification of Davis and Silverman [13]. The evaluation was performed in an acoustic booth with an Interacoustics Ad229 audiometer and TDH39 headset calibrated according to ISO-389 and IEC-645 standards. a-1) Speech recognition threshold: a list of disyllables was adopted, and the result was the intensity at which the participant scored 50% of the words presented. a-2) Speech recognition index: the test was performed with a list of monosyllabic words 40 dB above the mean tonal threshold of 0.5, 1, and 2 kHz and was considered normal if the number of correct answers was between 88 and 100%. b) Immittance audiometry (tympanometry and acoustic reflex): tympanometry was performed with a 226 Hz tone at 85 dB SPL with pressure swept from –400 to 200 daPa. Ipsilateral and contralateral acoustic reflexes were sought at 0.5, 1, 2, and 4 kHz. Subjects presented peak maximum compliance around 0 daPa and an equivalent volume of 0.3 to 1.3 mL according to the proposal of Jerger [14]. Immittance audiometry was performed using an Interacoustics 235 h audiometer. All equipment was calibrated according to ISO-389 and IEC-645 standards. Both subjects presented normal answers in the basic audiological evaluation and proceeded to an electrophysiological evaluation of their hearing.

The electrophysiological evaluation was conducted using the Smart EP (Intelligent Hearing System, IHS) device in an acoustically prepared and electrically shielded room. The subjects were comfortably seated in a reclining chair. Before placing the electrodes, the subject’s skin was cleaned with abrasive paste. The electrodes were fixed with an electrolytic paste, and sticky tape was used to ensure a low impedance contact at positions Fz, Fpz, A1, and A2. The skin–electrode impedance was kept below 3 kΩ, and the inter-electrode impedance was kept below 2 kΩ. During testing, the subjects were instructed to keep their eyes closed to avoid artifacts. If necessary, changes were made to the subject’s position to ensure stable collection conditions. FFR stimuli were elicited using the 40 ms synthetic speech syllable /da/ provided by the Smart EP device. The stimulus consists of the consonant /d/ (transient portion or onset) followed by the short vowel /a/ (the sustained portion or frequency following response) [9,15,16]. The stimulus was presented monaurally to the right ear through ER-3A insert earphones with a repetition rate of 10.9/s at 80 dBnHL (alternating polarity) in quiet. Alternating polarities were used so as to cancel out neural responses from the cochlear microphonic and to reduce the effect of stimulus artifacts [17]. A time window of 60 ms (plus 40 ms pre-stimulus time) was used with an online filter of 0.1–3 kHz. Trials in which more than 10% of the sweeps were rejected were regarded as artifactual and repeated in order to obtain a reliable response with small artifact contamination. Two blocks of 3000 artifact-free sweeps were collected and averaged, resulting in a wave based on 6000 sweeps.

Once the diagnostic processes were completed, speech therapy rehabilitation sessions for dysarthria were begun, following the same structure in both cases. The therapy involved motor speech treatment aiming at adequacy, compensation, or adjustment of motor input [5]. In total, 25 rehabilitation sessions were held, each lasting 45 minutes, arranged as follows: a) 5 sessions aimed at respiratory intervention and rehabilitation; b) 5 sessions aimed at resonance intervention and rehabilitation; c) 5 sessions aimed at joint intervention and rehabilitation; d) 5 sessions aimed at prosody intervention and rehabilitation; and e) 5 sessions aimed at phonation intervention and rehabilitation.

The time between the completion of the 1st stage (pre-intervention) and the beginning of the 2nd stage (post-intervention) was 6 months for the two cases analyzed here.

Results and Discussion

Around the world, increases in life expectancy create an increase in the number of elderly people, and this can have an impact on many aspects of society, especially with regard to health policy [18]. Global action on health is needed so that the elderly can live with dignity, since they have a high prevalence of chronic diseases such as dysarthria [2,3,18].

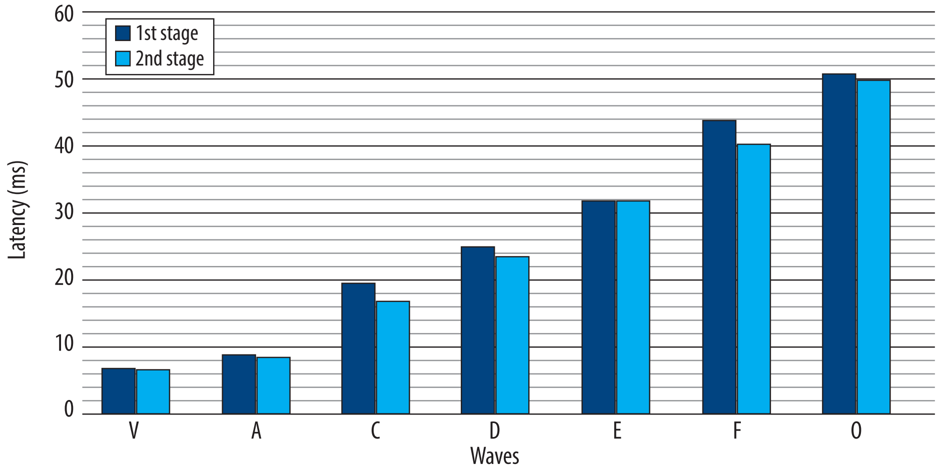
Dysarthria is the name given to speech disorders resulting from disturbances in the control mechanism due to damage to the central or peripheral nervous system; it reflects problems in oral communication due to paralysis, weakness, or incoordination of the speech muscles. It affects one or several of the five components of speech production: breathing, phonation, resonance, articulation, and prosody [4].

Dysarthria can negatively impact a patient’s daily activity and the purpose of the “Living with Dysarthria” questionnaire is to gauge the impact of this impairment on the patient’s quality of life [12]. The results of the questionnaire are presented in **Table 1**, and verify the perceived speech difficulties in individuals with dysarthria at the 1st and 2nd stages. The table shows a significant decrease in the total score after the specific speech therapy intervention for dysarthria (2nd stage of the study) compared with the

Table 1. Responses of subjects 1 and 2 in the "Living with Dysarthria" self-assessment questionnaire during the 1st and 2nd stages of the study; each response is out of a maximum of 30 points

Domain	Subject 1			Subject 2		
	1st stage	2nd stage	Difference	1st stage	2nd stage	Difference
Speech problems	21	5	16	16	13	3
Language/cognition problems	18	8	10	18	14	4
Tiredness	20	5	15	20	6	14
Effects on emotions	20	5	15	19	15	4
Effects on different people	19	5	14	20	5	15
Effects in different situations	24	5	19	17	5	12
Possibility of being affected by communication difficulties	21	5	16	26	5	21
What contributes to changes in your communication	23	8	15	24	10	14
How the communication is altered	20	10	10	23	7	16
Perception of changes and possibility of changing speech	20	7	13	22	10	12
Total	**206**	**63**	**143**	**205**	**90**	**115**

A



B

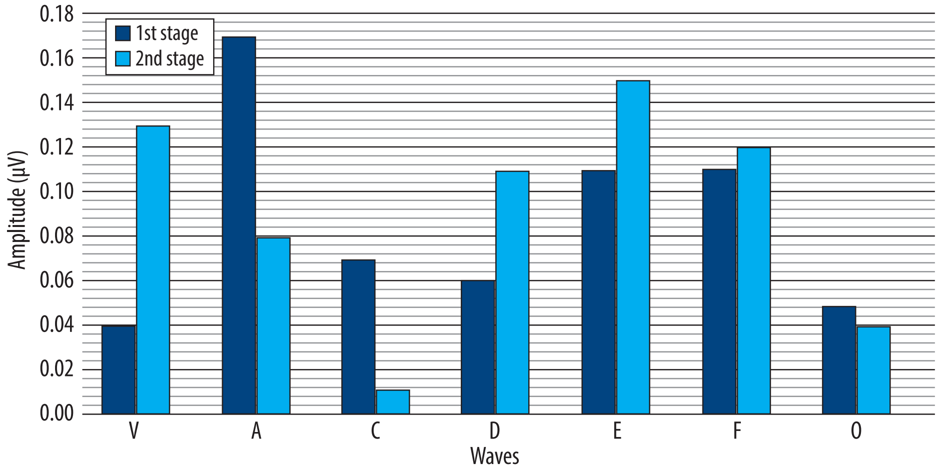


Figure 1. Changes in the FFR responses of subject 1 before (1st stage) and after (2nd stage) the intervention program. There are decreases in the latencies of all waves (**A**) and increases in the amplitudes of waves V, D, E, and F (**B**)

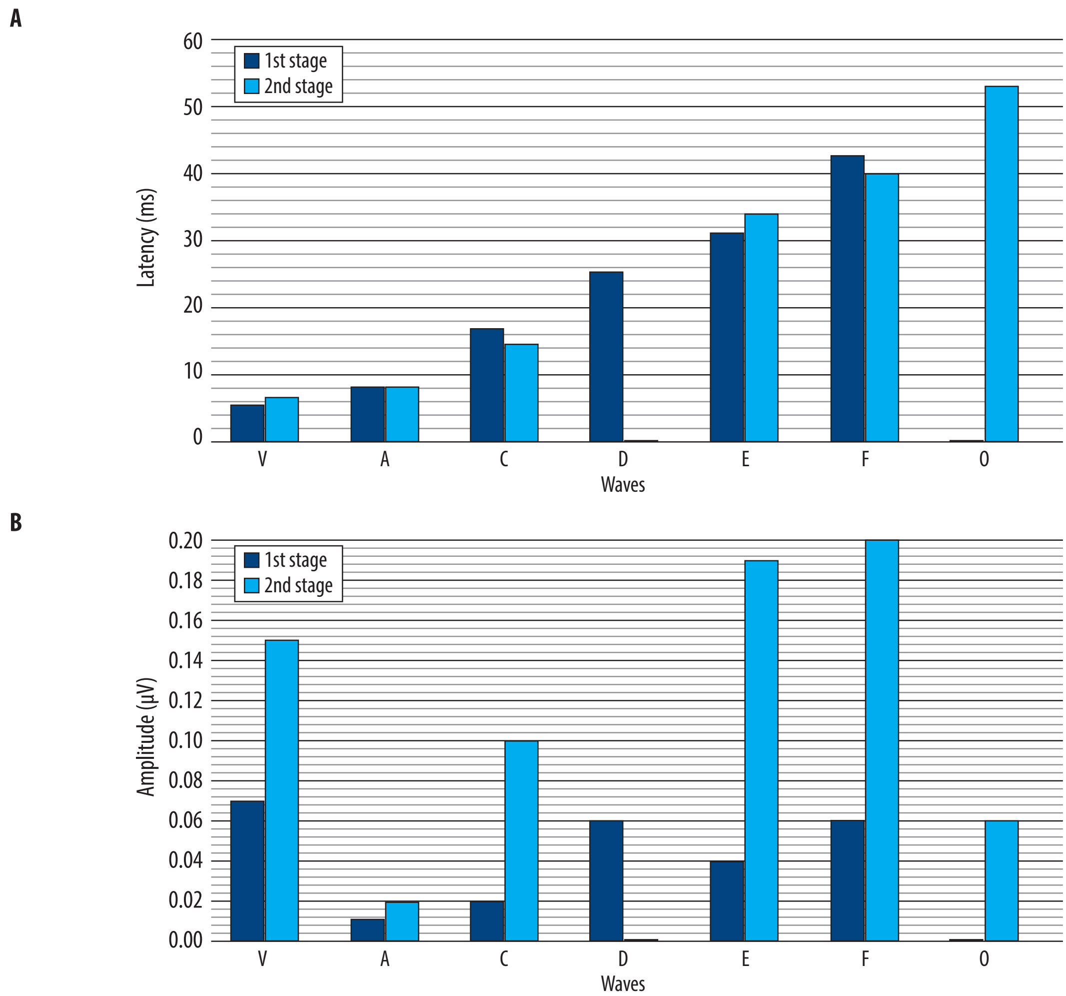


Figure 2. Changes in the FFR responses of subject 2. There are decreases in the latencies of waves C and F (**A**), and increases in the amplitudes of waves V, C, E, F, and O (**B**)

initial responses (1st stage of the study). This demonstrates a reduction in the impact of dysarthria on the quality of life of these subjects.

Both subjects showed improvements in all domains of the questionnaire, pointing to a significant improvement in their well-being. The use of a self-assessment protocol is valuable, since patients with neurodegenerative diseases such as PD (subject 1) or ALS (subject 2) may experience some type of cognitive change in the early stages of their disease, even if the motor symptoms are mild [19,20]. Cognitive deficits can include lapses in memory, attention, executive function, visuospatial capacity, language, and a decreased capacity for abstraction, and these can severely affect the quality of life of dysarthric patients. The questionnaire gives an insight into the effectiveness of therapy and how much it improves cognition and language, for example, aspects that are often impaired in dysarthria [19–22].

Self-assessment questionnaires can help monitor patients with dysarthria and are generally recommended. At the same time, objective methods such as FFR can, as biomarkers, help diagnose and monitor neurological diseases [1]. Dysarthria results from alterations to the central or peripheral nervous system, while speech production involves a complex system that requires not only planning and motor execution, but also depends on the participation of auditory inputs [6]. Thus, finding an effective biomarker of central auditory nervous system function would be very useful.

Electrophysiological assessments have previously been used in dysarthric patients. It has been reported that the long-latency auditory evoked potential, the P300, appears to be one important biomarker of pathology progression [23]. Similarly, event-related auditory evoked potentials, such as the mismatch negativity (MMN), have been shown to be relevant in assessing individuals with neurological disorders, as they provide objective measures [24].

However, in general, there has been a dearth of research involving neurological changes and FFRs. There is one report of an increased FFR latency in a group of patients with neurological disorders compared to a control group, indicating that the disorder may not relate just to a motor deficit, but also involve alterations in the neural coding of speech [25]. In the present study, the FFR responses were analyzed at two different stages, and responses compared after a speech-language pathology rehabilitation program.

The inter-subject reproducibility of FFR responses has already been proven, and this opens the way for using FFRs to monitor intervention and rehabilitation programs [15].

Figure 1 illustrates changes in the FFR responses of subject 1. There are decreases in the latencies of all waves, and increases in the amplitude values of waves V, D, E, and F. In comparison, **Figure 2** shows changes in the FFR responses of subject 2, which are decreases in the latencies of waves C and F, and increases in the amplitude of waves V, C, E, F, and O. In particular, wave O was not apparent at the 1st stage.

Although both subjects showed certain improvements in FFR responses, it appears that the benefits were more noticeable on the amplitude measure (with an increase in values) compared to the latency measure (with a decrease in values). However, it is important to note that, as seen in **Table 1**, subject 1 showed a better improvement from the speech-language pathology intervention than did subject 2. The increase in amplitudes is possibly associated with a strengthening of neuronal activation through an increase in the number of synapses [26] which in turn may have resulted from the speech-language intervention process. The intervention aimed to stimulate breathing, resonance, articulation, prosody, and phonation [5] through exercising skills involved with auditory inputs [6].

Using the FFR to evaluate and monitor the CANS could help monitor the progression of dysarthria, which may have affected the limbic, cognitive, auditory, and sensorimotor systems. The FFR assessment uses a verbal sound stimulus that activates several structures along the central auditory nervous system. In this way, the FFR is able to access the responses originating from the CANS [9–12,16].

In the present study the FFR confirmed the responses observed in the "Living with Dysarthria" questionnaire. The differences in responses between the subjects in the questionnaire and in the FFR may be due to the subjects themselves, since subject 1 was diagnosed with Parkinson's disease and hypokinetic dysarthria, while subject 2 was diagnosed with amyotrophic lateral sclerosis and mixed dysarthria (flaccid + spastic).

The FFR shows promise in monitoring neurophysiological changes since it follows the sound trajectory from the brainstem to the cortex [16]. It therefore might help us understand complex pathologies such as dysarthria, which affect a wide range of systems [9–12,16].

Study limitations

In the present study, the subjects were both male, and so in a new study female patients need to be included. In a future study, patients presenting the same type of dysarthria could help verify whether there are similarities in the FFR responses after rehabilitation. A greater number of patients and the presence of a control group would assist in rigor.

Conclusions

The present study suggests that the FFR may be a promising approach to monitoring the progress of speech therapy rehabilitation. It also seems that the self-assessment questionnaire may be useful in gauging the quality of life of dysarthric patients. However, this pilot study was carried out on only two patients, and so more studies are required using a larger sample size.

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