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Case reports

Ultrasound images of the tongue prior and post speech therapy

Imagens de ultrasonografia de língua pré e pós terapia de fala

Roberta Michelon Melo[1]
Roberta Freitas Dias[1]
Helena Bolli Mota[1]
Carolina Lisbôa Mezzomo[1]

[1] Universidade Federal de Santa Maria – UFSM – Santa Maria (RS), Brasil.

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Mailing address:
Roberta Freitas Dias
Av. da Cavalhada, 4530 (T8/203), Cavalhada
Porto Alegre – RS – Brasil
CEP: 91470-000
E-mail: robertafdias@hotmail.com

ABSTRACT

The aim of this study was to analyze the ultrasound imaging of the tongue movement during the production of alveolar and velar stops, before and after speech therapy. A boy of a five year old and with Speech Disorder participated in this study. Were collected the articulatory data (ultrasound imaging of the tongue movement) and perceptive hearing of [t], [d], [k] and [g], before and after the 25 speech therapy sessions. Regarding results obtained in pre-therapy moment, when observing the three repetitions of the tongue curve of velar stops, a gestural indifferentiation was apparently detected, suggesting the presence of a dependency between the organizers of tip and body of the tongue. In the after therapy, a change in the tracing of the tongue gesture of [k] and [g] was verified. They started presenting a posteriorization of the tongue movement, synchronously with a rise in its body, as the adult standard. Thus, ultrasonographic findings were able to show a possible overcoming of the anteriorization stop velar, detected in the first perceptual speech analysis. In addition, these results seemed to reinforce the idea of covert contrasts in the speech of children with speech disorders.

Keywords: Speech, Language and Hearing Sciences; Speech Therapy; Speech Disorders; Ultrasonography

RESUMO

O objetivo deste estudo foi analisar a imagem de ultrassonografia do movimento de língua durante a produção de oclusivas alveolares e velares, pré e pós-terapia de fala. Um menino com cinco anos de idade e diagnóstico de desvio fonológico, apresentando o processo de anteriorização de oclusivas velares, participou da presente pesquisa. Foram coletados os dados articulatórios (imagem de ultrassom do movimento de língua) e perceptivo auditivo dos fones [t], [d], [k] e [g], antes e após 25 sessões de terapia. Quanto aos resultados obtidos no momento pré-terapia, aparentemente, foi detectada uma indiferenciação gestual ao serem observadas as três repetições da curva de língua das oclusivas velares, sugerindo a presença de uma dependência entre os articuladores de ponta e corpo de língua. No momento pós-terapia, uma mudança na configuração do gesto de língua de [k] e [g] foi verificada. As curvas passaram a apresentar uma posteriorização do movimento de língua, sincronicamente com uma elevação do seu corpo, concordando com o padrão adulto. Dessa forma, os achados de ultrassonografia foram capazes de evidenciar uma possível superação da estratégia de anteriorização de oclusivas velares, detectada em análise perceptiva auditiva inicial. Além disso, estes resultados pareceram reforçar a ideia de contrastes encobertos na fala de crianças com desvio fonológico.

Descritores: Fonoaudiologia; Fonoterapia; Distúrbios da Fala; Ultrassonografia

INTRODUCTION

Speech data analysis has received, lately, contribution by instrumental apparatus such as spectrography, ultrasound and palatography. The use of technology has propitiated more accurate and reliable interpretation of typical and atypical speech data[1-3]. About phonological disorders, there are discussions about their nature: cognitive, articulatory or both of them.

Phonological disorders are defined as deficit in one of the language subsystems, characterized by difficulty of speech sounds organization, concerning the phonological system[4]. Children who present these phonology disorders use repair strategies for longer period of time in comparison with children with typical phonological development[5].

The repair strategies are mechanisms used by children during their phonological development, as an attempt to produce segments and/or syllabic structures which they do not know or whose production they do not control[5]. Studies indicate that as higher the disorder severity, higher is the number of used repair strategies (for example, devoicing, anteriorization and cluster reduction)[5,6].

Under another point of view, in the case of Articulatory Phonology[7] or Gestural Phonology[8-11], speech is interpreted as a dynamic task. This theory suggests that speech difficulty in phonological disorders occurs, mainly, because of two types of gestural changes: 1) reduction in magnitude (time and space) of individual gestures and; 2) increase of gesture overlap[11].

Speech therapy in these cases used several instruments to validate actions. It is common the use of evaluation protocols, usually subjective, to define different stages and procedures of therapeutic processes. In the scientific environment, there is increasing search for tools and more direct analyzes of phonoarticulatory organs, aiming at providing more accuracy of evaluative methods, as well as outlining diagnostic hypotheses[12,13].

In literature, there are several therapy models for phonological disorders, which differ in relation to theoretical bases, therapeutic procedures and way of application. Most of these models have as premise the reorganization of children's phonological system, considering the necessity of systematic cognitive reorganization. An example is the therapy model which was used in the present study: the Modified Maximal Opposition Model. This model foresees, if necessary, the performance of articulatory exercise, with tactile, kinesthetic and auditory tracks, to help children to produce target sounds individually, as well as to help in the performance of correct point and manner of articulation of these sounds[14].

The visual feedback during speech therapy has also been an alternative of instruments application such as electropalatography, nasometry, ultrasound, etc, which have presented positive results in the treatment of several speech alterations[15-18].

The articulatory analysis enables the direct detection of articulatory movements, especially in relation to posterior tongue movements[19]. In case of ultrasound images, they are considered as noninvasive and with minimal interference in the visualization of intraoral movements[19,20]. The use of ultrasound allows the professional to perform articulatory analysis of evaluated subjects data and of the patient in therapeutic process[15,16,21]. It is believed that this resource may contribute, when interpreted with other speech data, to monitor the therapeutic process evolution of children with phonological disorders expressing, or not, evidences of articulatory adjustments in the production of sounds which are stimulated in therapy.

Therefore, the purpose of this study was to analyze ultrasound images of tongue movements during the production of alveolar and velar stops, before and after therapy, in a case of phonological disorder, with the presence of velar stop anteriorization.

CLINICAL CASE PRESENTATION

The present study is a clinical case report, longitudinal, qualitative, performed at the school clinic from Federal University of Santa Maria, linked to the Brazilian Unified Health System.

The data presented in this case report are part of a research project approved by the university research ethics committee, number 14973013.8.0000.5346. The participant children's guardians signed the free and clarified consent term, authorizing data collection and use for scientific research.

The presented clinical case is a boy, C., who is five years old and presents diagnosis of phonological disorders, and is monolingual Brazilian Portuguese (BP) speaker. In the first speech auditory perceptive analysis, it was observed velar stop anteriorization, and other repair strategies. He had not received any type of previous speech and language therapy.

The diagnosis of phonological disorder was defined based on a series of speech therapy evaluations

(anamnesis, oral expressive and comprehensive language, stomatognathic system, articulatory examination, speech evaluation through the setting of phonetic and phonological inventories and hearing evaluation) and complementary examinations, otorhinolaryngologic and neurological.

The subject was submitted to speech therapy, through the Modified Maximal Opposition Model[14], broadly applied and referenced by national literature. This model indicated the use of minimal pairs (words that are different from each other only because of a phoneme), which maximally contrast. It means that they differ in one or more distinctive features (/g/ x /r/ à *Ma**g**a* x *Ma**r**a*). In the case of C., the only selected sounds to be stimulated were /g/ x /r/, inserted in the following minimal pairs: *Maga x Mara* (a proper name); *bagulho* (stuff) x *barulho* (noise); *paga* (pays) x *para* (stop, for, to). Twice a week, a total of 25 therapy sessions were performed.

For this study, C.'s data from recordings (audio and video) obtained from evaluations of the phonetic and phonological systems and ultra sound images, before and after therapy, were analyzed.

In order to evaluate the phonetic and phonological systems, it was used the Children Phonological Assessment (CPA)[4]. This evaluation allows the achievement of a sample with all sounds of the BP phonological system, in all positions they can occur in syllables and words. After collected, the data were transcribed through the International Phonetic Alphabet and reviewed, in a perceptive way, by two evaluators with experience in phonetic transcription. Then, it was performed contrastive analysis and it was established the C.'s phonetic and phonological systems, through auditory perceptive analysis.

For the ultrasound data recording procedure, the following equipments were used: microphone (*Shure – SM48*); endocavity transducer (*65C10EA*) attached to a portable ultra sound machine (*Mindray – DP6600*); computer; synchronizer; sound box and head stabilizer (*Articulate Instruments Ltd)*.

Before the speech sample collection, it was requested the subject to fill the oral cavity with water, modifying, thus, the impedance value in relation to the bone structure, facilitating the hard palate visualization. So, some seconds of water swallowing were recorded with the aid of ultrasound ecquipment[22].

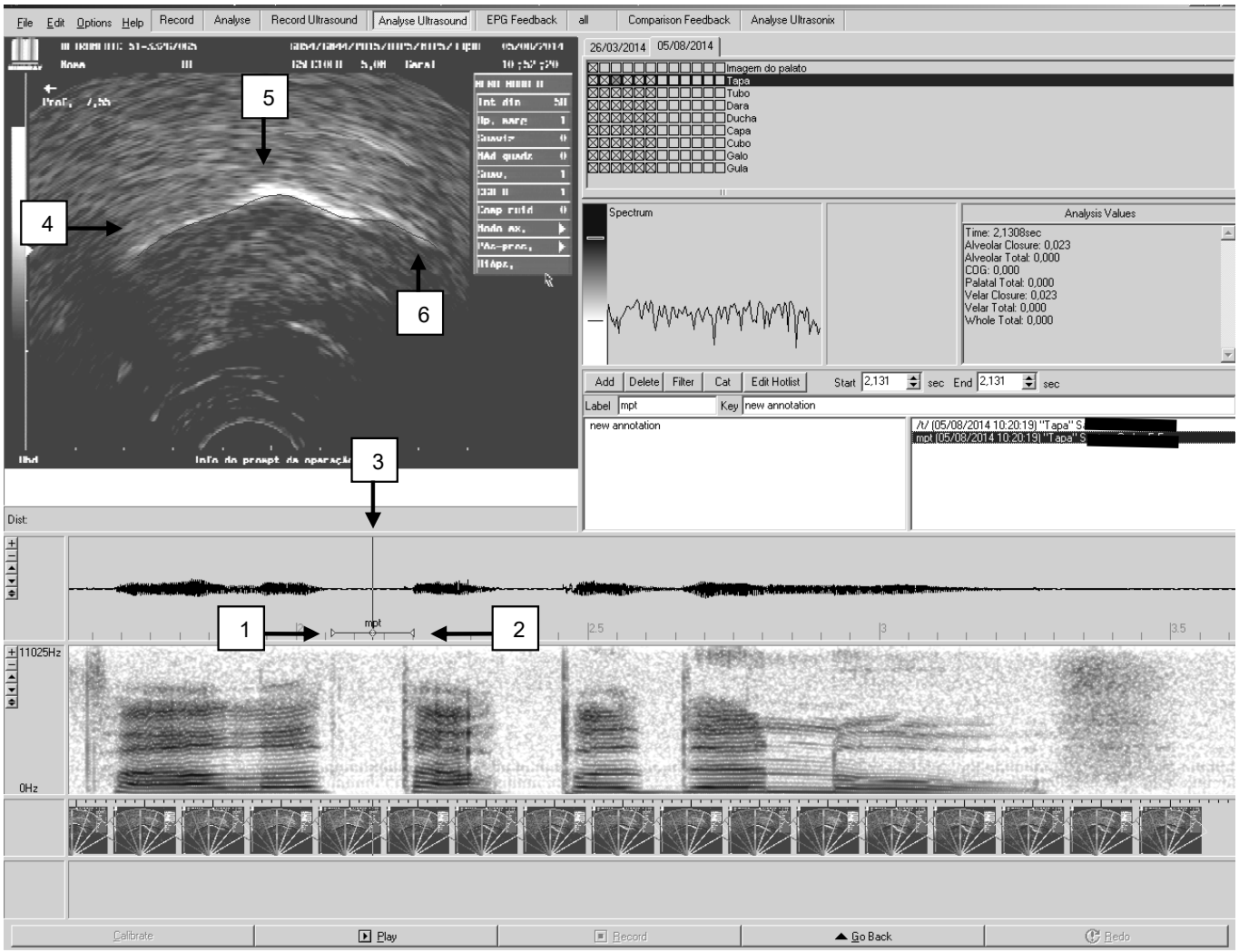
The articulatory data (ultrasound images of the tongue movement) of /t/, /d/, /k/ and /g/ were collected through spontaneous naming of the words – /'kapə/, /'kubo/, /'tapə/, /'tubo/, /'galo/, /'gulə/, /'darə/ e /'duʃə/. These words were represented through pictures and they were presented through computer screen to be named. The subject was instructed to include the target word in the vehicle sentence *"Fala ____ de novo" (Say _____ again)*. Each target word was named six times, however, for the present study, the analyzed words were only words whose consonant is in the context of the vowel /a/ and only in the three first repetitions. Therefore, 12 of C.'s productions were analyzed.

During the recording, the subject remained seated, in upright posture, into an acoustic cabin. The ultrasound transducer was positioned on the submandibular region and fixed, attached to the head stabilizer (*Articulate Instruments Ltd)*. C. was guided to name the pictures in usual vocal pattern (intensity, frequency and speed), under supervision of a researcher who remained into the cabin. The collection time of ultrasound images varied from 15 to 25 minutes, performed in two sessions.

The articulatory analysis of the collected data using ultrasound was performed through the *Software Articulate Assistant Advanced (AAA*) - (*Articulate Instruments Ltd)*. To do so, it was selected the instants which correspond to the production of each segment (/t/, /k/, /d/ e /g/). It means that based on the spectrogram provided by the program, it was guided by the acoustic register related to the end of the second vowel of the word "Fala" (speech) (last regular cycle of the vowel), to the beginning of the vowel following the stop consonant to be analyzed.

Also using the *Software AAA*, the tongue movement images were captured and analyzed. It was performed an outline on the tongue surface (on sagittal section) in the instant which corresponds to the consonant midpoint.

For instance, in Figure 1 it can be visualized the *Software AAA* window, with the spectrogram and tongue ultrasound image of one of the analyzed segments.



Legend: 1 – Acoustic correlative regarding the end of the second vowel /a/ of the word "Fala" (Say) and beginning of the stop /t/; 2 – Acoustic correlative regarding the end of the stop /t/ and beginning of the vowel /a/ following the stop; 3 – Midpoint of the stop /t/; 4 – Curve of the tongue traced in the midpoint of the production of the stop /t/; 5 – Tongue body; 6 – Tongue tip.

Figure 1. Articulate Assistant Advanced (AAA) software window - (Articulate Instruments Ltd), with spectrogram and ultrasound image of tongue during the production of the stop /t/, in the carrier phrase: '*Fala* ***tapa*** *de novo*' (Say slap again)

However, the articulatory analysis was based on the description of the tongue curve outline in the midpoint of the target consonants production. The interpretation of the tongue images was based on gestural descriptors[11,23] proposed by the Gestural Phonology. They are supported by the tract variables, which correspond to the constriction actions of the vocal tract organs and their reference with the related articulators[7]. The considered variables were:

- Place of tongue tip constriction (PTTC);
- Degree of tongue tip constriction (DTTC);
- Place of tongue body constriction (PTBC);
- Degree of tongue body constriction (DTBC).

In order to classify the tract variables and consequent description of the tongue curve outlines, it was established and agreement among the three Speech Therapists with experience in the speech field.

RESULTS

In relation to the data obtained through CPA, or from auditory perceptive analysis of C.'s speech, it was identified, before therapy, the presence of velar stops anteriorization (/k/à[t] and /g/à[d]), and other repair strategies. In the final phonological evaluation, or, after 25 therapy sessions, it was verified overcoming of observed processes of speech, before starting speech and language therapy.

The ultrasound data, analyzed through the Software AAA before therapy, specifically in relation to the alveolar stops, revealed tendency to raise the tongue tip in the midpoint of consonant production (analyzed during the production of the words /'tapə/ and /'darə/), supporting the expected pattern and the initial auditory perceptive analysis, which did not identify the occurrence of /t/ and /d/ omission and/or substitution in the studied subject's speech (Figures 2 and 3).

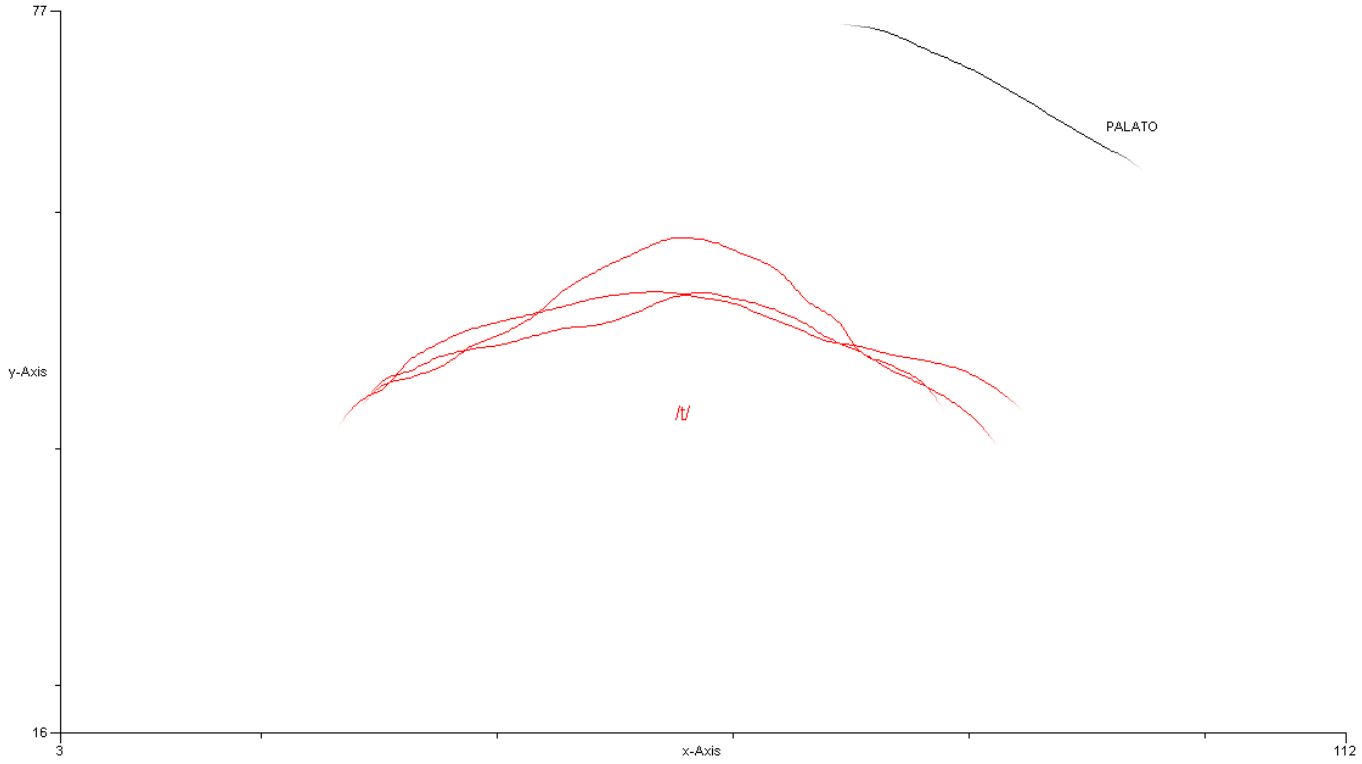


Figure 2. Data before therapy, tongue curves traced on the midpoint of the stop /t/, in three repetitions of the speech-target

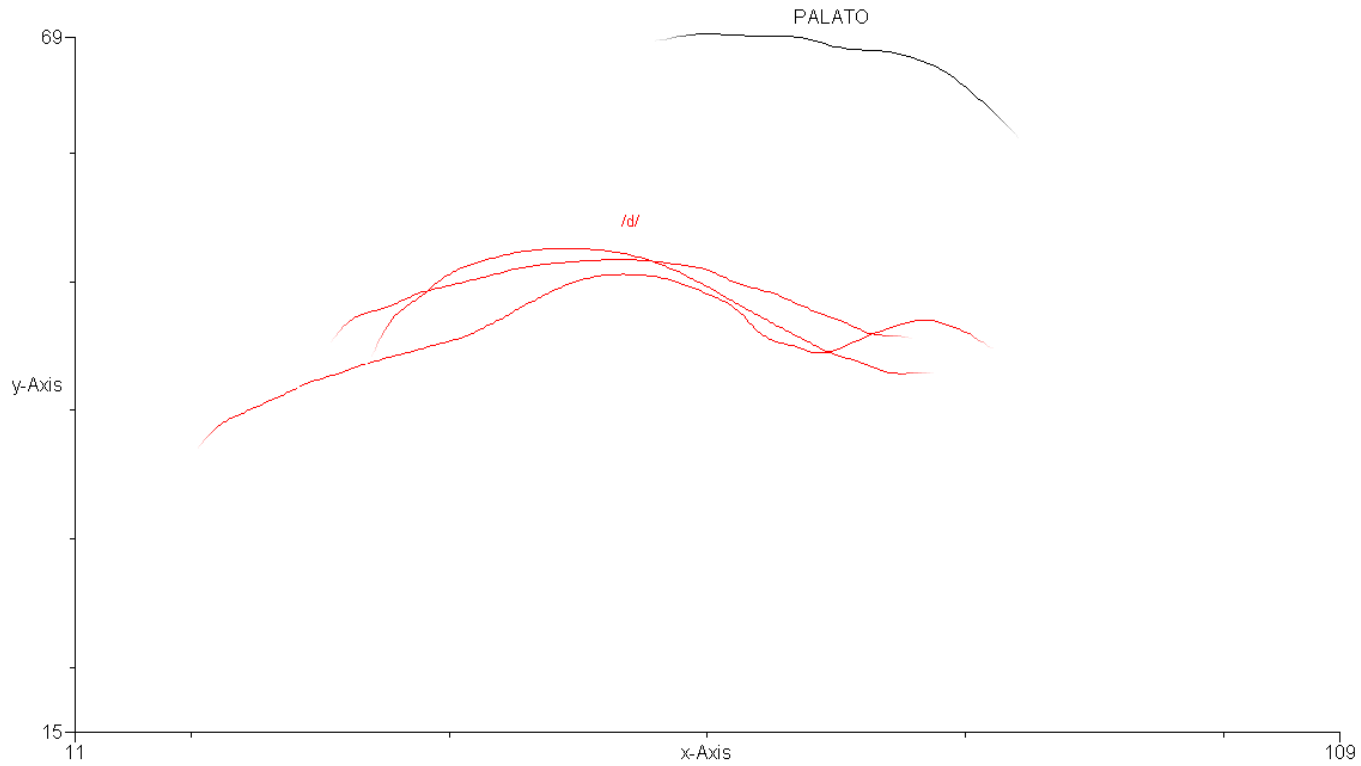


Figure 3. Data before therapy, tongue curves traced on the midpoint of the stop /d/, in the three target-words repetitions

However, in relation to the stops /k/ and /g/, auditorily produced as /t/ and /d/, it was detected indifferentiation of tongue gestures, suggesting dependence between articulators of tongue tip and body. This finding was observed in all three tongue curve repetitions related to the production of both velar stops (Figures 4 and 5).

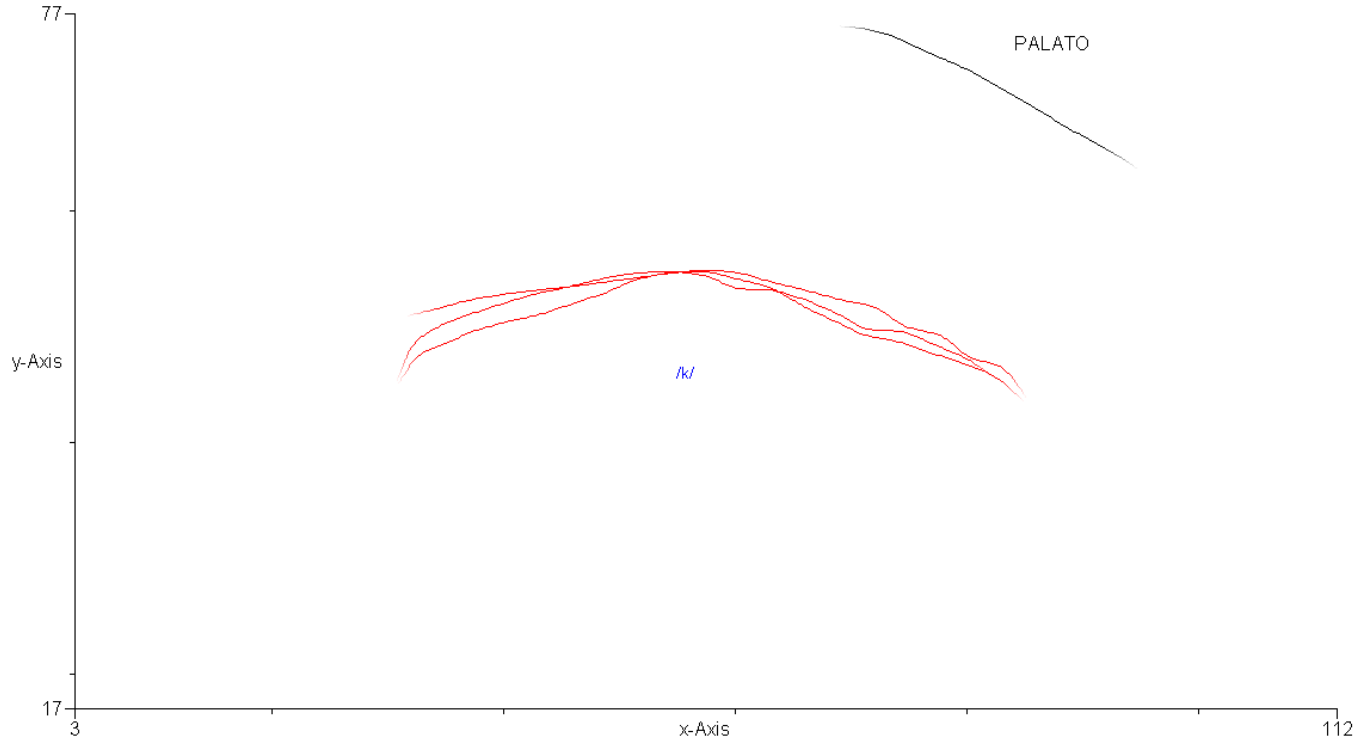


Figure 4. Data before therapy, tongue curves traced on the midpoint of the stop /k/, in the three repetitions of the target-word

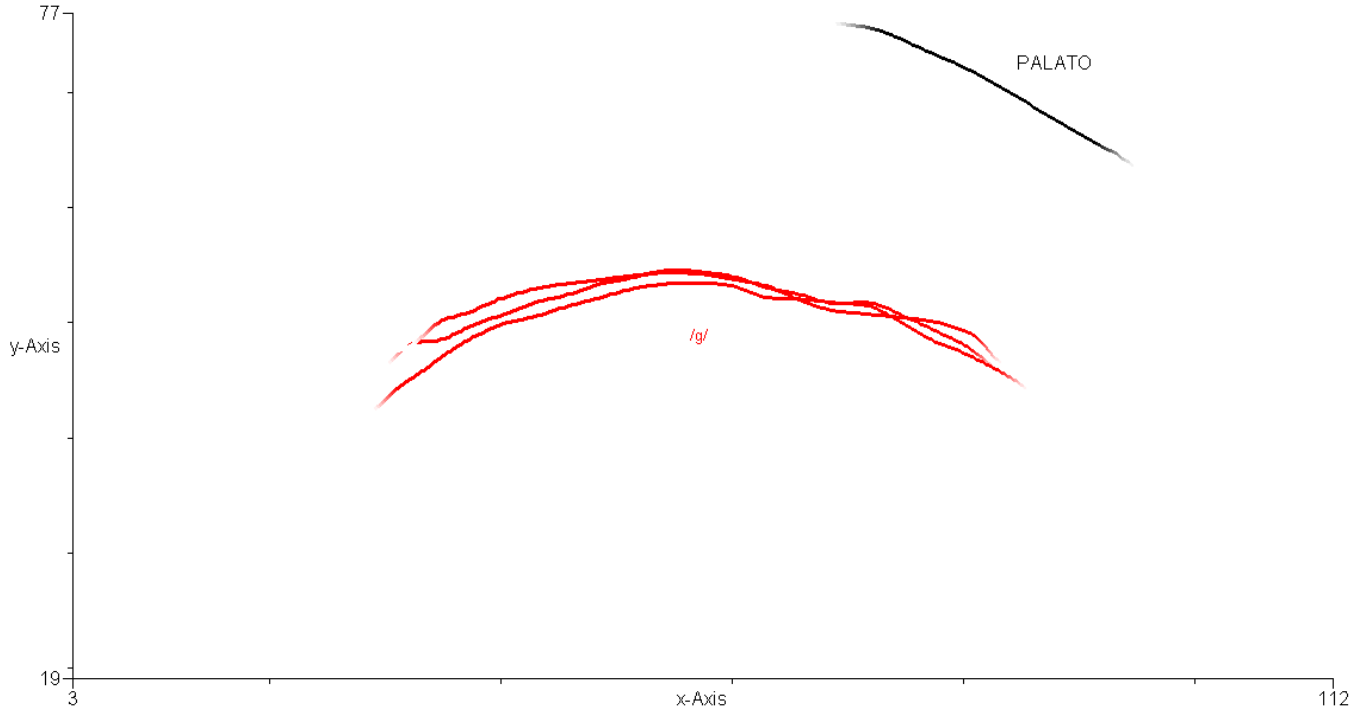
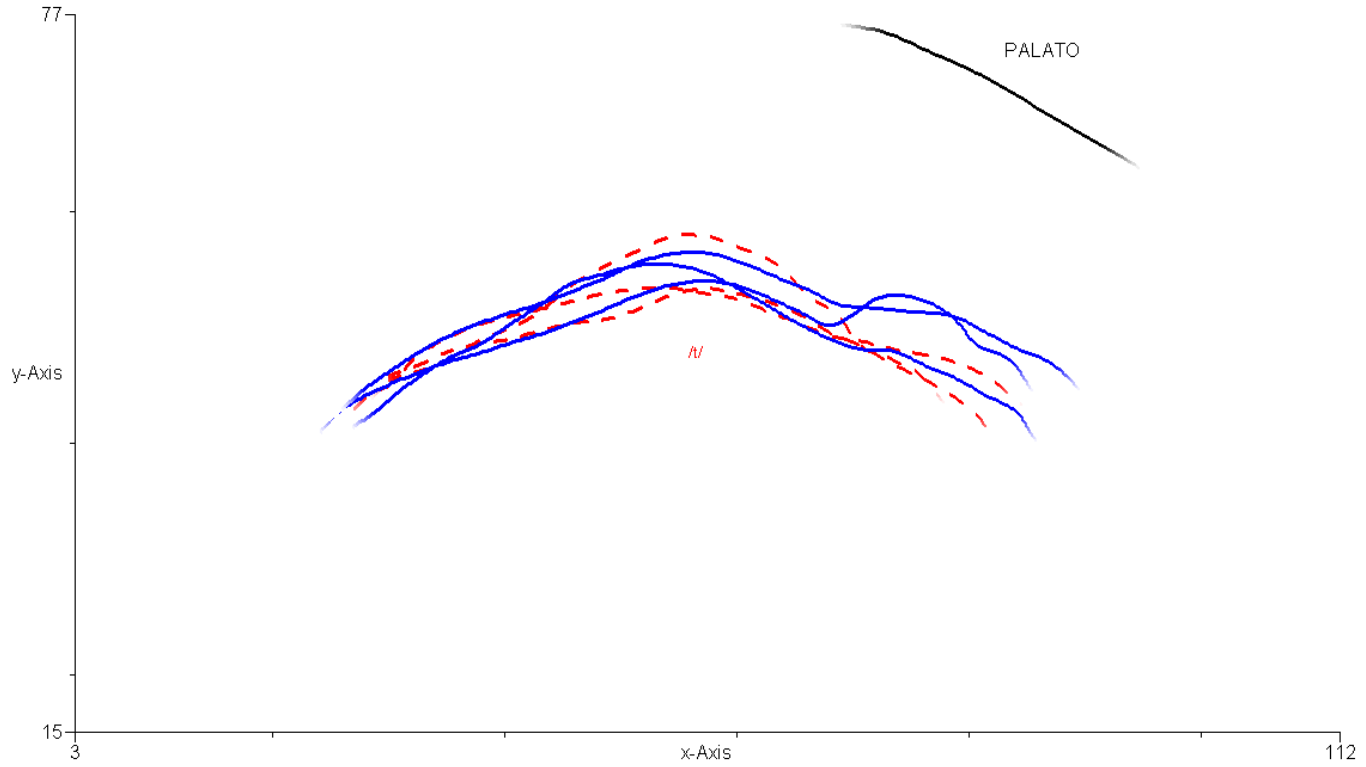


Figure 5. Data before therapy, tongue curves traced on the midpoint of the stop /g/, in the three target words repetitions

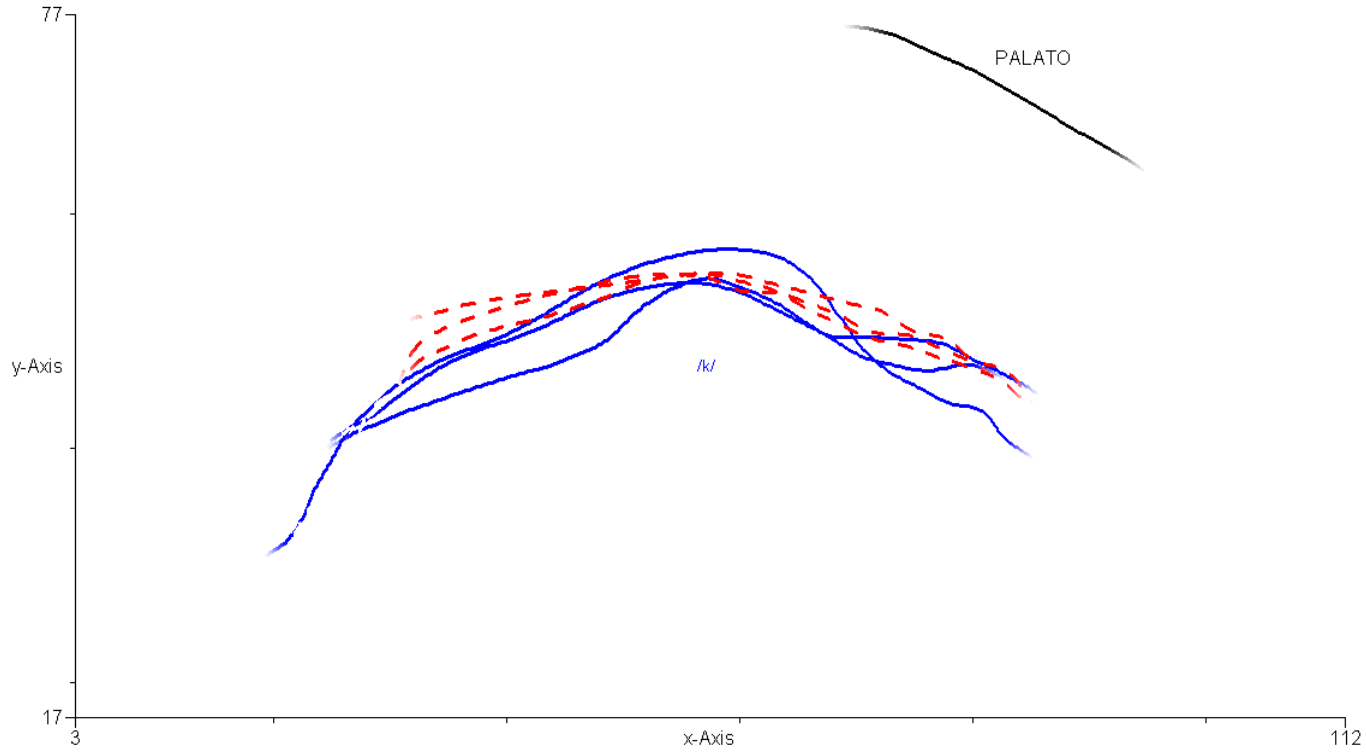
Thus, it not possible to categorically state that the tongue curves which correspond to the velar stops treat the same tongue outlines observed to /t/ and /d/. This result suggests the occurrence of a possible "intermediate state between the contrastive phones".

On the other hand, in the comparison of data before and after therapy, it was observed change in the configuration of the tongue gesture to velar stops. In this moment, it is presented posterization of tongue movement, synchronously to a body elevation, agreeing with the adult pattern understood by human ears (Figures 6, 7, 8 and 9).



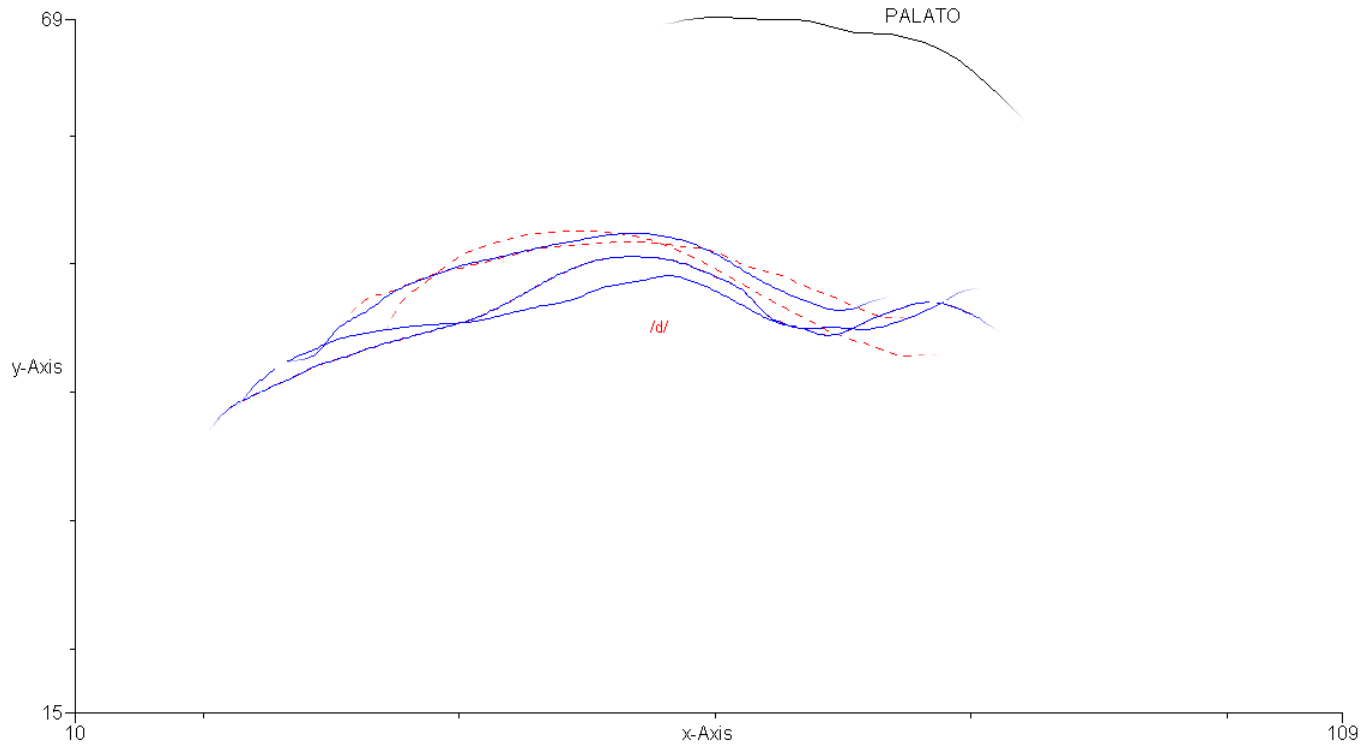
Legend: Dotted line – data before therapy; Continuous line – data after therapy.

Figure 6. Tongue curves traced on the midpoint of the stop /t/ - before and after therapy data



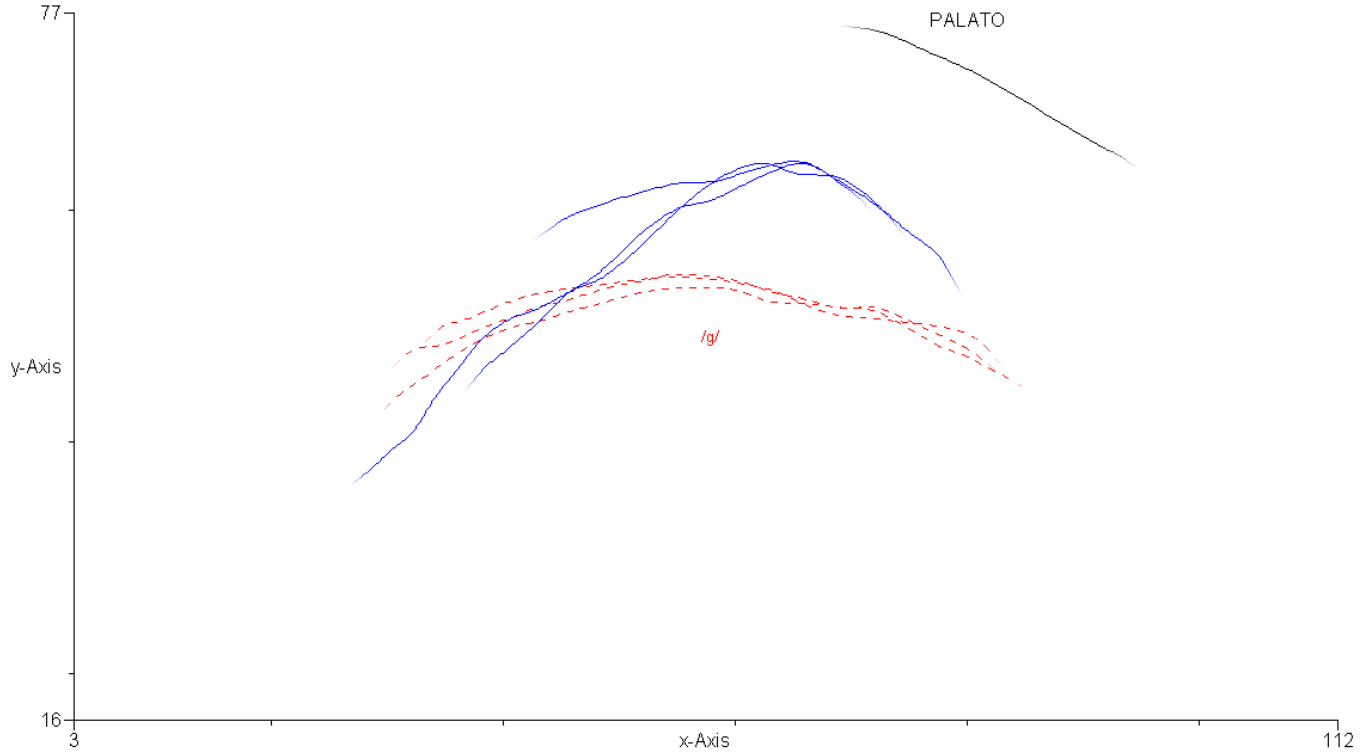
Legend: Dotted line – data before therapy; Continuous line – data after therapy.

Figure 7. Tongue curves traced on the midpoint of the stop /k/ - before and after therapy data



Legend: Dotted line – data before therapy; Continuous line – data after therapy.

Figure 8. Tongue curves traced on the midpoint of the stop /d/ - before and after therapy data



Legend: Dotted line – data before therapy; Continuous line – data after therapy.

Figure 9. Tongue curves traced on the midpoint of the stop /g/ - before and after therapy data

DISCUSSION

Before the speech therapy beginning, the subject with diagnosis of phonological disorders, investigated in the present study, presented tongue anteriorization into the oral cavity, associated with tip elevation during the production of alveolar stops. Even with no reference of the passive articulator (alveolus, in this case), it is supposed that there is production of a tongue tip gesture, with closed degree. This tongue curve configuration agrees with some of the gestural descriptors proposed by the gestural phonology[11].

However, in relation to the velar stops, produced as alveolar (/k/→[t] and /g/→[d]), according to auditory analysis, it was identified dependency between the gestures of tongue tip and body, different from the expected for these segments. Thus, it is possible to infer immaturity of articulatory gestures during /k/ and /g/ production.

In a certain way, the ultrasound findings before therapy may refer the idea of covert contrast, as the velar stops, identified through auditory perceptive analysis as replaced by alveolar stops, do not correspond to the same tongue gestures used in the production of /t/ and /d/.

The existence of gradient productions and covert contrasts in 'errors' which are usually classified as categorical has been proved through consistent data[8,9-11,24-26].

The identification of this type of contrast is only possible through the use of an instrumental methodology (acoustic and/or articulatory), which enables the understanding of which are, and in which magnitude, the acoustic and articulatory parameters have been employed to distinguish several speech sounds[26].

As mentioned earlier, a gestural indifferentiation seems to be occurring during /k/ and /g/ production before the beginning of speech therapy. In speech typical data, using the tract variables to describe the set of articulatory gestures[11,23], it would be expected tongue direction to the anterior region of the oral cavity, simultaneously with tip tongue elevation to produce alveolar constriction (/t/ and /d/). During the production of the velar constriction (/k/ e /g/), it would be expected tongue movement posteriorization, associated with tongue body elevation. Even without soft palate images through ultrasound, it is believed that there is gesture production with closed degree[11].

Next, some stages of the articulatory gestures development are described: in an initial period of speech motor control, children learn to distinguish articulators; then, with the neuromotor control refining, there is differentiation intra-articulators, for example, between tongue body and tip, important to the contrast between alveolar and velar stops, and; finally, it would occur the adjustment of constriction degree and place of these articulators[27].

In the case of C., there seems to be a disadjustment in the implementation of the second stage, mentioned earlier. It is also detected the dependency between the tongue body and tip articulators. These results have already been mentioned in another study which reviewed electropalatography in children with articulatory/phonological disorders[28].

However, after 25 therapy sessions, it was observed change in C.'s tongue gesture pattern, similar to the pattern described to speech without alterations[29]. It also agrees with what was previously described in relation to the tract variables (tongue body constriction place and degree) involved in the production of a velar constriction[11]. Thus, development of gestural complexity could be observed with the comparison of the outlines of tongue curves, before and after speech therapy.

It is interesting to highlight the importance of the instrumental analysis, as it is not possible to capture the gradient production and the covert contrasts only with auditory analysis. Although the use of this resource, in the C. case, reaffirms the effectiveness of the speech therapy with phonological basis to overcome the phonological disorders[14], factors such as phonological disorders nature are, again, questioned.

Even with therapeutic procedures which are strongly enshrined in the field of phonological disorders, the Speech Therapy area seems to advance in the search for instrumental procedures in clinical practice. Simultaneously with this will, there is the necessity of more research in this scope, for instance, with the insertion of new equipment for visual feedback of the articulators involved in the target-sounds production, as through ultrasound information, as through other types of articulatory investigations.

FINAL CONSIDERATIONS

The articulatory analysis of the studied subject data, through ultrasound, before and after therapy, contributes, with the auditory data, to the evaluation and determination of the prognostic in this case.

The use of this technological apparatus reaffirmed the effectiveness of the therapy model with phonological basis, but, on the other hand, it raised issues

such as: would it be possible to affirm the occurrence of phonemes substitution? In this case, the tongue curves regarding the production of velar stops should not present the same tongue outlines observed during the production of alveolar sounds, should it? The dependency of tongue body and tip articulators would not be aiming at the existence of covert contrasts, would it? Therefore, could the phonological disorder difficulty be related to a difficulty caused by the neuromotor control refining?

As it was previously referred, studies about the use of technologies are innovative to the speech area in Brazil. The topics instigated in this study should keep motivating the research development, so the Speech Therapy field could acquire more knowledge to make the phonological disorders understanding and therapy more effective.

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