

# Comparison of articulatory gestures between men and women in the production of sounds /r/, /l/ and /j/

## Comparaç o dos gestos articulat rios entre homens e mulheres na produç o dos sons /r/, /l/ e /j/

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### ABSTRACT

**Purpose:** To analyze the tongue gestures of adults with typical speech development obtained by ultrasound evaluation and to compare them, according to gender, in the production of phonemes /r/, /l/ and /j/. **Methods:** Thirty adults aged 19 to 44 years old participated in the research, being 15 males and 15 females. Articulatory gestures were captured by Model DP-6600 ultrasound and analyzed using AAA (Articulate Assistant Advanced) software. Fifteen words involving the sounds /r/, /l/ and /j/ were selected in different vowel contexts: /a/, /i/, /u/. All words were represented by figures, included in the same carrier phrase. The images of the articulatory gestures visualized on the ultrasound corresponded to the frames relative to the maximum elevation of the tongue tip in the productions of /r/, /l/ and /j/. Afterwards, the tongue gestures of men and women were compared in order to verify gender-related differences. **Results:** In the typical adults surveyed, there were double tongue gestures. The coordination of gestures of /r/, /l/ and /j/, associated with the various vowel contexts, revealed different tongue configurations between men and women. In women, for /r/ and /l/, there was lower root retraction and higher tongue tip elevation when compared to men. In the /j/, the tongue dorsum gesture was very similar in men and women. **Conclusion:** In typical adults, in /r/ and /l/ there are two simultaneous tongue gestures: tip and root of tongue. In /j/, there is the tongue dorsum gesture. In the qualitative analysis of the words, for /r/ as well as for /l/, in different vowel contexts, there was a slight elevation of the tongue tip and root retraction in women compared to men.

**Keywords:** Speech; Acoustics of speech; Ultrasound; Adult; Speech therapy

### RESUMO

**Objetivo:** Analisar os gestos de l ngua de adultos com desenvolvimento t pico de fala obtidos pela avalia o ultrassonogr fica e compar -los, quanto ao sexo, na produ o dos fonemas /r/, /l/ e /j/. **M todos:** Participaram da pesquisa 30 adultos com idades entre 19 e 44 anos, sendo 15 do sexo masculino e 15 do feminino. Os gestos articulat rios foram capturados pelo ultrassom Modelo DP-6600 e analisados por meio do *software* AAA (*Articulate Assistant Advanced*). Foram selecionadas quinze palavras que envolveram os sons /r/, /l/ e /j/, em diferentes contextos voc licos: /a/, /i/, /u/. Todas as palavras foram representadas por figuras, inclu das em uma mesma frase-ve culo. As imagens dos gestos articulat rios visualizadas no ultrassom corresponderam aos *frames* relativos   eleva o m xima da ponta da l ngua nas produ es de /r/, /l/ e /j/. Ap s, os gestos de l ngua de homens e mulheres foram comparados, a fim de verificar diferen as relacionadas ao sexo. **Resultados:** Nos adultos t picos pesquisados houve duplos gestos de l ngua. A coordena o dos gestos de /r/, /l/ e /j/, associados aos variados contextos voc licos, revelou diferentes configura es de l ngua entre homens e mulheres. Nas mulheres, para /r/ e /l/, observou-se menor retra o de raiz e maior eleva o da ponta de l ngua, quando comparadas aos homens. No /j/, houve o gesto de dorso de l ngua de forma muito semelhante em homens e mulheres. **Conclus o:** Nos adultos t picos, em /r/ e /l/ h  dois gestos de l ngua simult neos: ponta e raiz de l ngua. No /j/, h  o gesto de dorso de l ngua. Na an lise qualitativa das palavras, tanto para /r/, quanto para /l/, em diferentes contextos voc licos, observa-se discreta eleva o de ponta de l ngua e retra o de raiz nas mulheres, em compara o aos homens.

**Palavras-chave:** Fala; Ac stica da fala; Ultrassom; Adulto; Fonoaudiologia

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## INTRODUCTION

Speech production demands a complex coordination between the organization, planning and execution of speech movements. It is a skill that depends on the functional learning of motor praxes, which are acquired through interaction with the speech production itself, and not only through the neuromaturation process<sup>(1,2)</sup>.

Instruments, both in research and clinical practice, in order to analyze speech production, facilitate the understanding of certain sounds, providing a more accurate and reliable interpretation of typical and atypical speech data<sup>(3-6)</sup>. Among these instruments, tongue movement ultrasonography (USG) stands out, still recently used in Speech Therapy, but with important contributions in diagnosis and intervention<sup>(7-10)</sup>.

Over the past three decades, USG has been adapted to measure tongue movement with considerable success because it is a non-invasive, discrete method that provides clear images of the tongue surface and movements made to produce a certain sound can be observed.

Studies involving instruments such as USG have emerged as a way to rethink the relationship between phonetics and phonology, interpreted by the dynamic model of speech production, known as Gestural Phonology (FonGest)<sup>(11)</sup>, based on Articulatory Phonology (FAR)<sup>(12)</sup>. In this model, the phonological structure of the tongue is described as a set of articulatory gestures<sup>(13)</sup>.

The model seeks to combine mechanical and physical (phonetic) as well as linguistic and cognitive (phonological) aspects, in which the articulatory gesture operates as the basic unit<sup>(14)</sup>. It is not only represented by the movement of the articulators, but also by the variables of the vocal tract (protrusion and lip opening, place and degree of constriction of the tongue tip, place and degree of constriction of the tongue dorsum, velic opening and glottal opening)<sup>(12)</sup>.

A study<sup>(15)</sup> aimed at evaluating, in adult population, the influence of gender, body height and race on orofacial anthropometric measurements, showed that men have larger orofacial anthropometric dimensions than women. Another study<sup>(16)</sup> found that the angle between the hard palate and soft palate in men is greater than in women.

Research using magnetic resonance imaging<sup>(17)</sup> reported that excess fat in the submandibular region is more pronounced in men than in women. In addition, the study found that men also have a typically larger tongue than women<sup>(18)</sup>. Another research<sup>(19)</sup> established that the mean mouth opening in men reached 45.13 mm and, in women, 42.88 mm, thus being higher in males.

In a study<sup>(20)</sup> on the production of sibilants with the use of tongue ultrasound, it was reported that the smaller dimension of the oral tract influences the visualization of the tongue contour for the production of these sounds. All this evidence shows that there may be gender differences in the production of articulatory gestures, but there are no studies on the comparison of tongue movements obtained by USG images between men and women. It is believed that because there are orofacial anatomophysiological differences between men and women, the articulatory gestures analyzed by tongue movements ultrasonography can detect them.

Liquid consonants /r/ and /l/ are known to belong to the later acquisition class in typical speech development, due to their complexity for production<sup>(21)</sup> in Brazilian Portuguese (BP).

Given this, there is a need for studies that help characterize these segments, that is, the understanding that the production of these sounds would involve the coordination of two simultaneous gestures (tip and body of the tongue), as demonstrated in American studies that described the gestures of /r/ and /l/<sup>(22)</sup>.

Coronal glide /j/ often occurs in the natural tongues and is phonetically sound continuously and without friction. In typical BP phonological acquisition, the production of /j/ is linked to the environment of diphthongs or triphthongs. The ease of production of /j/ is due to the fact that this sound presents a single, less complex articulatory gesture of the tongue, that of the tongue dorsum, towards the palate<sup>(23)</sup>.

In Brazil, there are still recent research that described the articulatory gestures involved in the production of speech sounds<sup>(24-29)</sup>. Therefore, this study aimed to analyze the tongue gestures of adults with typical speech development obtained by and to compare them according to gender, in the production of phonemes /r/, /l/ and /j/.

## METHODS

This study is part of a doctoral research of a higher education institution. It is a field research, quantitative, qualitative, descriptive, exploratory and prospective. Thirty Brazilian Portuguese-speaking adults (BP) from the city of Santa Maria/RS participated in the study, being 15 males and 15 females, aged 19 to 44 years old, chosen by convenience.

Participants signed the Informed Consent Form (ICF), as required by the Research Ethics Committee of the Federal University of Santa Maria, which approved the study under protocol No. 442,786. The evaluated subjects were volunteers and accepted to perform the evaluations after previous and detailed explanation about the procedures contained in the ICF.

All subjects met the criteria for inclusion of speech-language evaluations (audiological, orofacial motricity, comprehensive language, expressive language, learning and voice) within the normal range. Data collection was performed in the speech/language sector of a higher education institution. The time taken to collect the ultrasound images for each subject ranged from 20 to 40 minutes, being performed in a single session. Tongue movements were recorded individually using a one-way microphone (SHURE - SM48), portable ultrasound, model DP 6600, with a microconvex transducer, coupled to a compute.

Image signals were captured and analyzed using Articulate Assistant Advanced (AAA) software<sup>(29)</sup>. The corpus used in the recordings consisted of 15 words represented in images, in the segments /r/, /l/ and /j/. For the choice of words, the following vowel contexts were considered to the segments /r/, /l/ or /j/, being: /a/ of the words “cala” [‘kalɐ] (shut up), “cara” [‘karɐ] (face), “caia” [‘kajɐ] (fall down); /i/ of the words “cari” [‘kari] (own name), “cali” [‘kali] (own name) and “cai” [‘kaj] (falls) and /u/ of the words “caro” [‘karu] (expensive), “calo” [‘kalu] (callus), “caio” [‘ka.ju] (own name), in unstressed syllable. The second word list consisted of words also in the following vowel contexts of /a/ in the words “barata” [bɛˈratɐ] (cockroach) and “salada” [sɐˈladɐ] (salad), /i/ of the words “ferida” [fiˈridɐ] (wound) and “falida” [fɐˈlidɐ] (bankrupt) and /u/ of the words “charuto” [ʃɐˈrutu] (cigar) and “cabeludo” [kɐbɛˈludu] (hairy), in stressed syllable. From each subject, six repetitions of each word were inserted, inserted in the same carrier phrase (“speak \_\_ word \_\_ again”).

In the two lists of proposed words, the following was considered: in the first list - disyllable words, minimal meaningful pairs, that can be represented in images, with the targets in unstressed syllable, that is, /r/, /l/ and /j/ with the vowels /a/, /i/ and /u/ in the following context; in the second list - trisyllable and polysyllable words, meaningful, that can be represented in images, with the targets in stressed syllable, that is, /r/ and /l/ with the vowels /a/, /i/ and /u/ in following context. No word with /j/ was included in the second list, because only the first word list (disyllables) allowed meaningful words. The inclusion of /j/ in the second list would entail including meaningless words, which would undermine the purpose of the study because meaningless words require different attention and memory than meaningful words.

The AAA program displays an image on the computer screen, corresponding to the word that the subject must produce, and has an audible flag that warns the start of recording and the start of speech production. All participants received prior explanations of word repetitions by inserting them into the same carrier phrase. Thus, each carrier phrase containing the target word was repeated six times. Wordlist nominations always followed the same order of presentation until the completion of the six repetitions for each word. The analyzes of the productions were obtained in a single collection.

During the collection, the head stabilizer (Articulate Instruments Ltd.) was used, allowing the fixation of the USG probe in the submandibular region, ensuring greater reliability in the obtained data. The stabilizer is a helmet made of aluminum, weighing 800 grams and is adjustable at various points. The head stabilizer, by stabilizing the probe in the submandibular region, allows for reduced head movement variation and better image capture of the tongue. After collection, the frames corresponding to the segments /r/, /l/ and /j/ were analyzed, being chosen the one in which there was the maximum elevation of the tongue tip, supposedly representing the arrival at the target. An outline under the surface of the tongue, in sagittal section, was performed in the automatic extraction obtained by the AAA software.

In the images, the analysis of the frames corresponding to the maximum tongue elevation was performed by two speech therapists with experience in the speech area and in the handling of the program used in the collection, being the consensus among them the moment of the maximum elevation of the tongue tip, in each production. The tongue images were selected from the frame already described, in each segment /r/, /l/ and /j/ in the corresponding words. For each image, an outline of the tongue contour, in sagittal section, was performed in the visualization of the tip to the tongue root.

The tongue contours means for each of the 42 points of the tongue curves corresponding to the productions of each of the 30 subjects were entered in graphs, which demonstrate the articulatory gestures analyzed.

In the classification of gestures, the descriptors proposed by Gestural Phonology<sup>(11)</sup> were used, specifying the tract variables that correspond to the constriction actions of the vocal tract organs and their reference with the articulators involved<sup>(12,29)</sup>.

The treatment variables considered for the qualitative descriptions of the articulatory gestures involved in the production of sounds were as follows: 1) place of tongue tip constriction (LCPL); 2) tongue tip constriction degree (GCPL); 3) oral constrictor guidance; 4) place of tongue body constriction (LCCL); 5) tongue body constriction degree (GCCL). In the description corresponding to /r/, /l/, /j/, the following were

considered: tongue tip as articulator and respective anterior constriction place, being the guidance of the apic-laminal or alveolar articulator. The degree of constriction of the articulators selected as a descriptor was that of open-ended tip (referring to approximants) and narrow. In addition to place and degree of constriction, the number of gestures involved and whether or not they belonged to the same oral subsystem was considered.

The analysis of the articulatory gesture between the genders was performed comparing the /r/ and the /l/, being the /j/ used as a parameter of comparison. The gestures performed for the production of /r/ and /l/ are similar: tongue tip elevation in the alveoli region and tongue root retraction towards the pharynx. In the gesture to produce /j/, there is the movement of the tongue dorsum towards the hard palate<sup>(30)</sup>. The qualitative analysis of the articulatory gestures was performed after the calculation and outline of the means of the tongue curves by gender (quantitative analysis).

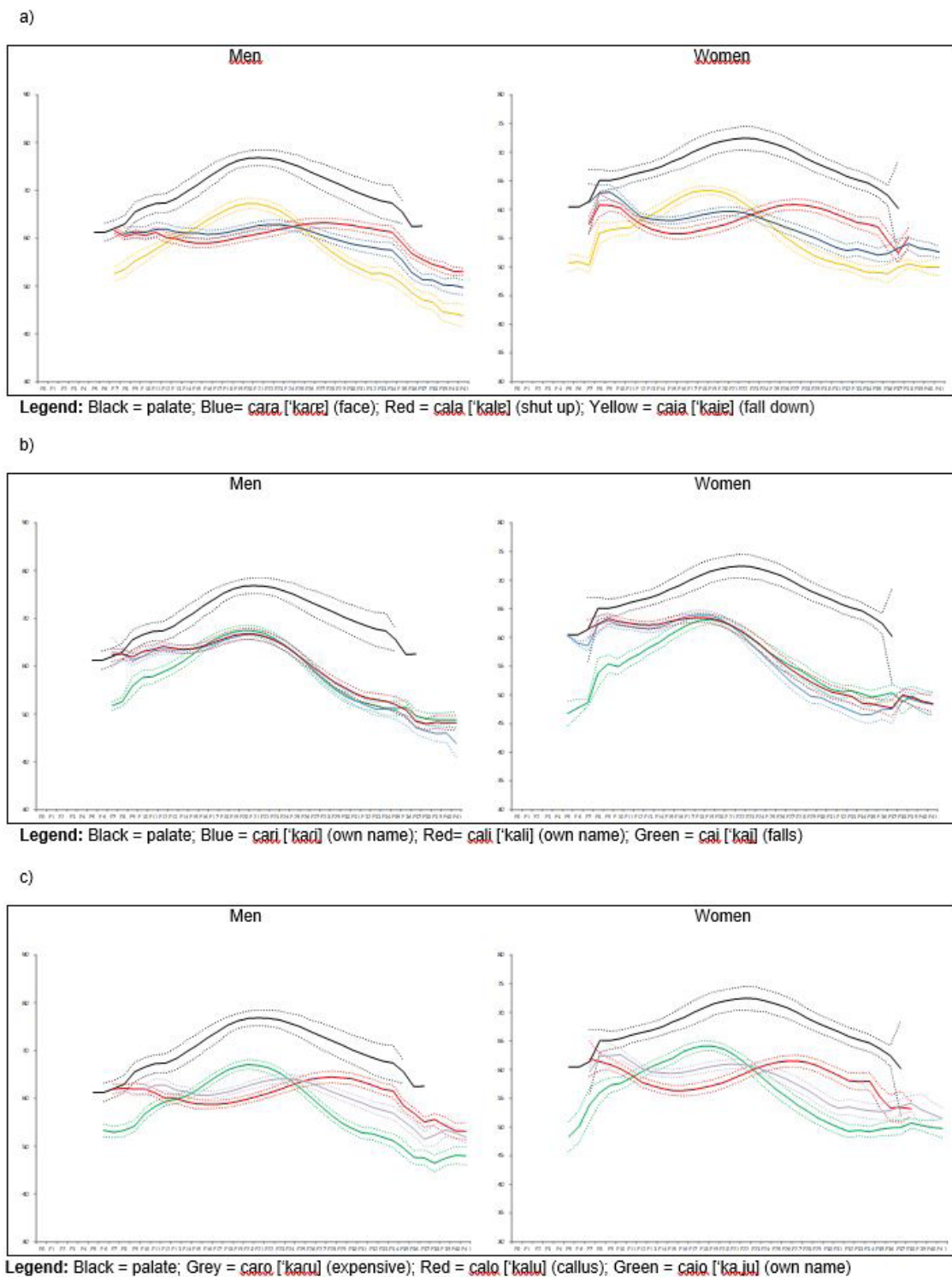
## RESULTS

The means of the tongue surface contours (in millimeters) of each subject, for the segments /r/, /l/ and /j/, in the vowel context of /a/, in the production of the words “cala” [‘kalə] (shut up), “cara” [‘karə] (face), “caia” [‘kajə] (fall down), in the vowel of /i/, in the production of the words “cari” [‘kari] (own name), “cali” [‘kali] (own name) and “cai” [‘kaj] (falls) and in the vowel context of /u/, in the production of the words “caro” [‘karu] (expensive), “calo” [‘kalu] (callus), “caio” [‘ka.ju] (own name) are represented in Figure 1, respectively.

For the production of /r/ in “cara” [‘karə] (face), both genders performed two gestures simultaneously, that of tongue tip elevation, in anterior and alveolar constriction, and retraction of the tongue root, towards the pharynx. For the production of /l/ and “cala” [‘kalə] (shut up), there were also two simultaneous gestures, the tongue tip elevation in anterior and alveolar constriction and the root retraction, towards the pharynx. Comparing the /r/ with the /l/, in both genders, it was noticed that, for the production of /r/, there was a higher tongue tip elevation and greater retraction of the tongue root than in /l/. As for the vowel context of the words, it was observed that the tongue was in central position in /a/. For the production of /j/ in “caia” [‘kajə] (fall down), there was a tongue gesture, dorsum elevation, therefore, a single articulatory gesture (Figure 1a).

For the production of /r/ in “cari” [‘kari] (own name) and /l/ in “cali” [‘kali] (own name), there were also two simultaneous gestures of the tongue, tip and root of the tongue. It was also noticed that the gesture was influenced by the following vowel /i/ to /r/, which, being the highest and anterior, positions the tongue more broadly when compared to the other words in the following vowel contexts of /a/ and /u/. For the production of /j/ in “cai” [‘kaj] (falls), there was a tongue gesture, dorsum elevation, therefore, a single articulatory gesture (Figure 1b).

For the production of /r/ in “caro” [‘karu] (expensive) and /l/ in “calo” [‘kalu] (callus), it can be seen in both /r/, and /l/, there were two tongue gestures, at the tip and root, with no distinction between the genders. It was also observed that, in relation to the analyzed context, the tongue had the maximum constriction in /r/ and /l/, very similar in relation to the genders. For the production of /j/ in “caio” [‘ka.ju] (own name), there was a gesture of tongue, dorsum elevation, therefore, a single articulatory gesture (Figure 1c).

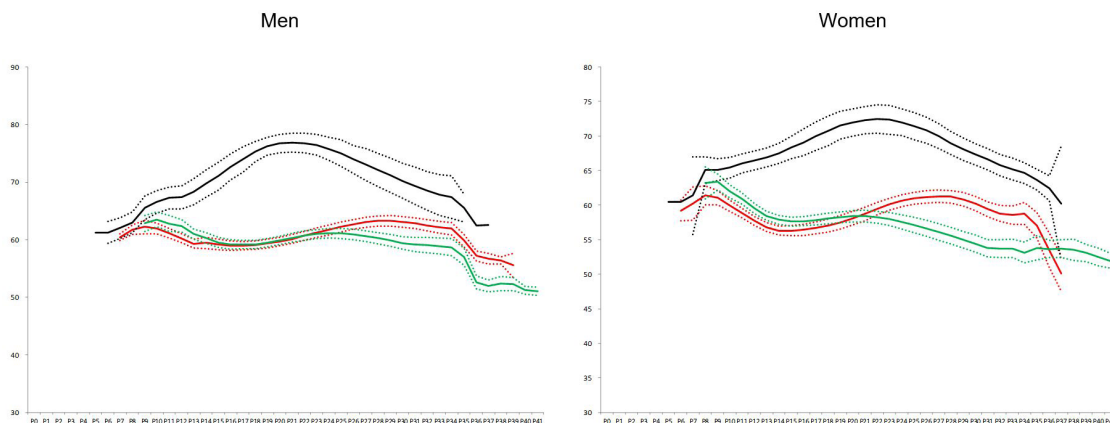


**Figure 1.** Means of tongue surface contours in the three vowel contexts in men and women

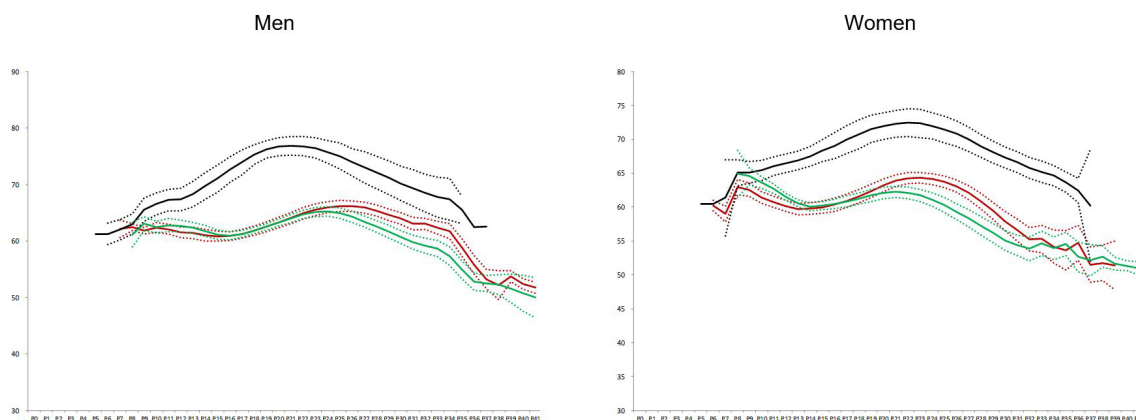
The segments /r/ and /l/, in the vowel context of /a/ following, obtained in the tonic words “barata” [bɐˈratɐ] (cockroach) and “salada” [sɐˈladɐ] (salad), in men and women, are shown in Figure 2.

In Figure 2, as in Figure 1a, it can be observed that the tongue was in a more central position, due to the vowel context /a/, with the presence of two simultaneous gestures, tip elevation

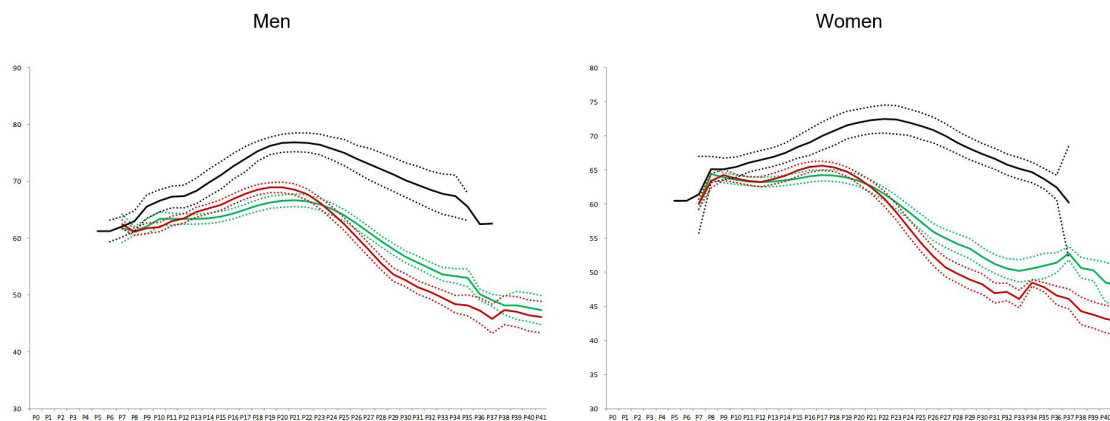
and root retraction. For the production of /l/ in “cala” [ˈkalɐ] (shut up), double simultaneous gestures, tip elevation and tongue root retraction were also noticed. In the production of /r/, in both genders, there was a higher tongue tip elevation and higher root retraction, when compared to /l/. In men, there was a greater retraction of the tongue root towards the pharynx in the production of /r/, when compared to women.



**Figure 2.** Means of tongue surface contours in vowel context of /a/ preceding and following  
**Legend:** Black = palate; Green = *barata* [be'ratε] (cockroach); Red = *salada* [sε'lade] (salad)



**Figure 3.** Mean of the tongue surface contours in the vowel context of /a/ and /e/ preceding and /u/ following  
**Legend:** Black = palate; Green = *charuto* [ʃε'rutu] (cigar); Red = *cabeludo* [kabe'ludu] (hairy)



**Figure 4.** Mean of the tongue surface contours in the vowel context of /a/ and /e/ preceding and /i/ following  
**Legend:** Black = palate; Green = *falida* [fε'lide] (bankrupt); Red = *ferida* [fi'ride] (wound)

The segments /r/ and /l/, in the vowel context following /u/, obtained in the context of stressed syllables in the words “charuto” [ʃε'rutu] (cigar) and “cabeludo” [kabe'ludu] (hairy), in both genders, are shown in Figure 3.

In Figure 3, both in /r/, and /l/, there was a gesture of tongue tip elevation and a gesture of root retraction towards the pharynx, in both genders, being the gesture of tongue root retraction toward the pharynx quite similar between men and

women. In females, there was higher tongue tip elevation in /r/ and lower retraction of the gesture of tongue root in /l/.

The segments /r/ and /l/, in the vowel contexts following /i/, in stressed syllables, the words “ferida” [fi'ride] (wound) and “falida” [fε'lide] (bankrupt), or men and women, are shown in Figure 4.

Figure 4 shows that, for the production of /r/ e /l/ there were also simultaneous double gestures of tongue, tongue tip elevation

in the alveolar direction and retraction of the tongue root towards the pharynx. During the production of the /r/ segment, there was a higher tongue tip elevation in women compared to men. In the production of /l/, the articulatory gestures of the tip and root of the tongue occurred very similarly for both genders.

## DISCUSSION

In this research, the articulatory gestures in the production of liquids /r/, /l/ and /j/ between adults, men and women were compared, using the USG for analysis of tongue movements. The USG allows to clearly visualize the surface of the tongue and observe the movements made to produce a certain sound<sup>(21)</sup>. The use of an instrumental methodology allows us to observe which, and in what magnitude, phonetic- acoustic parameters are being used to distinguish speech sounds<sup>(22)</sup>.

Given the above, it can be emphasized that the USG allows the observation of tongue gestures in normal adults, being possible, from the adult speech pattern, to obtain information that may provide parameters for adult deviant speech as well as typical and child deviant speech<sup>(10)</sup>.

The means of tongue surface contours, in men and women, in the /r/ and /l/, segments, allowed to observe qualitatively higher tongue tip elevation in women, in the productions of the words “cari” [ˈkari] (own name) and “cali” [ˈkali] (own name). For /r/ and /l/, there were simultaneous double tongue gestures (tongue tip elevation towards the alveoli and root retraction towards the pharynx), and the coordination of /r/ and /l/ gestures were intrinsically associated with different vowel contexts, with different configurations.

National and international studies using USG<sup>(18,21,22)</sup> also observed the presence of two simultaneous articulatory gestures in the liquid /r/ and /l/, confirming the findings of this research. The presence of double gestures in the production of liquids justifies the greater complexity in the acquisition and development of speech for these sounds<sup>(21)</sup>, /r/ and /l/, which require the coordination of gestures dependent on the same articulator, the tongue (tip and root of the tongue), and segments with multiple lingual constrictions will be acquired late<sup>(14)</sup>.

In this study, the ultrasound images of women were better than those of men. Other studies<sup>(18,20)</sup> reported that women tend to have a better USG image than men, due to the size of the oral cavity and the effectively smoother tongue surface.

Another study<sup>(31)</sup> using acoustic analysis of speech signals and tongue contour by ultrasound revealed that differences between genders in relation to formants were also found in ultrasound images. Women presented greater length of the posterior surface of the tongue and anterior oral cavity than men in the production of vowels /a/ and /i/.

Other researchers<sup>(32)</sup> performed a study to describe a USG imaging system for clinical investigation of oral-lingual function, but no significant difference between genders was reported.

Despite the difficulty in precisely defining the position of the tip of the tongue, especially for men, similarity was observed in the tongue curve configurations between men and women, with double gestures of tongue for /r/ and for /l/ and only one tongue gesture for /j/. The tongue surface contour may not be well seen in men in the articulation of high vowels, velar consonants and rapid sounds, as in the case of plosive consonants<sup>(31)</sup>.

In the analysis of the articulatory gestures of /r/ and /l/, although similar, when comparing the sound /r/ to the sound

/l/, in /r/ greater retraction of the tongue root gesture towards the pharynx was observed for all words, besides slight tongue tip elevation, except in the following vowel context /i/, perhaps because this vowel is higher and anterior. The findings agree with a study<sup>(21)</sup> that reported that /r/ involves greater coordination complexity than /l/, since the former imposes a simultaneous coordination between a ballistic movement of the tip of the tongue and a radical constriction towards to the pharynx. Another study also reported that /j/ presents only one tongue gesture, of dorsum, toward the central area of the hard palate<sup>(23)</sup>.

The USG was presented as an important instrument for analysis of the articulatory gestures of the tongue. This analysis becomes enlightening for speech studies, when one understands the dynamics of movement in the light of Gestural Phonology<sup>(33)</sup>. The analysis of speech production according to a dynamic model can understand the variability of rotic in BP, as well as the coordination of double constriction gestures and the influence of different vowel contexts on gestural configuration.

There is a large literature<sup>(4,7,9,14,20,22-28)</sup> using the means of tongue contours and images in the USG with the purpose of comparing age groups, pre-therapy and post-therapy, in different disorders of speech sounds, however, most refer to children and there are no studies comparing genders, adults, in the production of sounds /r/, /l/, /j/, highlighting the need to expand research that analyze this population. Methodological limitations do not allow the comparison of speakers with few subjects, since variables such as the positioning of the probe in the submandibular region and the dimensioning of overlapping images may compromise the reliability of possible applicable statistical tests.

The calculation of the means of tongue contours in a representative sample, as performed in this study, may contribute to obtain normalization strategies, constitution of methodological bases and expansion of technological resources for speech analysis in BP.

## CONCLUSION

The ultrasound evaluations of the tongue movements, comparing men and women, allow the analysis of the tongue gestures in the sounds /r/, /l/ and /j/, in different vowel contexts. Gestures of tip and root of tongue for /r/ and /l/ and tongue dorsum gesture in /j/, where, in the production of /r/ and /l/ in women, a slight elevation of the tongue tip and retraction of the tongue root compared to men is highlighted.

Tongue gestures are influenced by the vowel contexts presented. In the vowel context of /a/, the tongue occupies a lower central position in the oral cavity, in the vowel context of /i/, the tongue occupies a higher and anterior position, while /u/ also occupies a higher but posterior position.

The phonemes /r/ and /l/ present two simultaneous gestures of the tip and root of the tongue, which confirms greater linguistic complexity for the production of these segments, also in Brazilian Portuguese, while /j/ presents only one gesture of tongue. Tongue gestures for /r/, /l/ and /j/ are influenced by the vowel contexts of words.

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