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Articulatory Dynamics of Lateral and Trill Phonemes of Tamil and Telugu languages: An Ultrasound Study

Irfana Madathodiyil[a*], Sathya Santhoshini Reddy[b]

[a]*King Khalid University, Riyadh, Saudi Arabia*
[b]*Ashray Akruti Avt Center Sr Nagar, India*

A B S T R A C T

Compared to other sounds, /l/ and /r/ have much more complex and more variable articulatory configurations across speakers. The present study aims to find the articulatory dynamics of lateral /l/ and trill /r/ across two Dravidian languages, i.e., Tamil and Telugu. A total of 20 subjects from two language groups were taken for the study, with 10 participants from each language, which includes an equal number of males and females. Tongue contours for each subject were taken for /l/ and /r/ sounds in the VCV context. In Tamil, the posterior tongue height was more for /r/, and there was no difference in height in the mid-region and anterior region. In the /u/ context, tongue height was more for /l/. The statistical analysis of /l/ and /r/ in Tamil revealed that in the /a/ context, there was no significant difference in tongue advancement and tongue height. The tongue height for /l/ was more in the anterior region when compared to the /r/, but there was no significant difference in tongue advancement in the /i/context. The present study findings will be provided information regarding the tongue dynamics of trills and laterals in normal individuals across two Dravidian languages.

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1. Introduction

Lateral /l/ and trill /r/ are the two sounds that have complex articulation and several labial and lingual constrictions that vary depending on word position and between speakers (Gick, 2002; Oh, 2005). These sounds developed later in children in comparison with other speech sounds. According to the speech sound norms by the Goldman Fristoe Test of Articulation (2000), /l/ is mastered by the age of 5 years in all the word positions. Clinically, cases of "resistant" /l/ and /r/ are regularly seen, translating into significant levels of frustration for patients and therapists. Despite advances in research, /r/ misarticulation is still considered one of the most difficult sounds to correct and one of the most persistent speech errors in school-aged children (Clark, Schwarz, & Blakeley, 1993; Elbert & McReynolds, 1975). A recent survey conducted by Ristuccia (2004) revealed that many SLPs are not making adequate progress with students who have /r/ disorders. Words containing /l/ and /r/ are frequently the source of errors in automatic recognition systems (Espy-Wilson, 2001). Compared to other sounds, /l/ and /r/ have much more complex and more variable articulatory configurations across speakers. Compared to vowels or obstruent consonants, the acoustics and vocal tract models of /l/ and /r/ are less studied, except for some idealized articulation.

In this study, a comparison was made for the tongue contours of speech sounds in Telugu and Tamil, which are two Indian languages, belonging to the Dravidian language family. Telugu is the common language spoken in the district of Telangana and Andra Pradesh and Tamil is spoken in the state of Tamil Nadu. Based on Ethnologue website, Telugu has 1 million to 1 billion total users and Tamil has more than 66 million people at the beginning of the twenty-first century.

* *imadathodiyil@kku.edu.sa (Madathodiyil)*

The study conducted by Dhananjaya, Yegnanarayana, and Bhaskararao (2012) investigates the acoustic properties of apical trills. These trill speech sounds are produced by a periodic vibrating of the tongue apex. Ladefoged and Bhaskararao (1983) studied retroflex stops using X-rays. The retroflex stops in three languages were compared: Hindi, Tamil, and Telugu. The writers concluded that the retroflex stops in these languages differ. The tip of the tongue in Hindi retroflex stops is not as far back as it is in Dravidian retroflex stops, but Hindi retroflex stops are not the same as English alveolar stops. In the above-mentioned studies they have found the place of articulation of these sounds, but physiological studies using ultrasound are less, and still, there is no clarity about the exact place of articulation of these phonemes. Studies done by Charles et al., Tabain et al., and Campos have taken only one utterance into consideration, which will provide scope for large variability.

Studies were done to understand the characteristics of English lateral /l/ based on acoustic analysis and limited studies are there based on ultrasound imaging technique. One of the study reported of greater variability of /l/ production based on ultrasound analysis (Charles & Lulich, 2019). Campos (2020) to done an ultrasound study to check the tongue position during Spanish trill production and found that Ultrasound imaging can accurately determine the precise retracted tongue root position during the rhotic sound /r/ production. Another study was conducted to compare an Australian language, Arrernte, with Kannada. The authors found that the tongue back is consistently more back for the lateral manner of articulation and almost always more forward for the nasal manner (Tabain, Kochetov, Beare & Sreedevi, 2016).

As per the literature, there are few reported studies English and other Westers languages, however, no studies found on the articulatory dynamics of lateral sound /l/ and trill /r/ across two Dravidian languages. The present study aims to find the articulatory dynamics of lateral /l/ and trill /r/ across two Dravidian languages, i.e., Tamil and Telugu with the following objective: (a) To compare the horizontal displacement of the tongue across three points for the production of lateral and trills in Telugu and Tamil, (b) To compare the vertical displacement of the tongue across three points for the production of lateral and trill in Telugu and Tamil and (c) To find the language effect on horizontal and vertical displacement for the production of lateral and trill.

2. Methods

*2.1. Participants***:** A total of 20 subjects from three language groups were taken for the study, with 10 participants from each language, which includes an equal number of males and females. All of them were from 18 to 30 years of age and equitably considered Tamil and Telugu native speakers. The subjects were considered for the study after the screening of speech, language, and cognitive deficits based on informal assessment. A checklist, which was adopted by Johnson-Root (2015), was administered to rule out sensory-motor deficits of the participants. This checklist included all the articulators and provide provision to assess the structures and its functions in detail during speech and non-speech tasks.

*2.2. Materials***:** Tongue contours for each subject were taken for /l/ and /r/ sounds in the VCV context. The vowels accepted were the low central vowel /a/, the high front vowel /i/, and the high back vowel /u/.

Stimuli used for the study

Table 1

Vowels	**/r/**	**/l/**
Low	/ara/	/ala/
High front	/iri/	/ili/
Highback	/uru/	/ulu/

*2.3. Instrumentation***:** The micro-ultrasound system was used to obtain the tongue images, and the Articulate Assistant Advanced (AAA) ultrasonography module Version 2.17.07 was used for analysis with 60 frames per second.

*2.4. Procedure***:** Data collection was done individually after obtaining written consent. The patients were made to sit in a comfortable position. The participants were made to sit in a comfortable position. Before data collection, the procedure was explained to the participants briefly, and they were asked to have some water before starting the procedure so that the oral cavity was moisturized for better images from the ultrasound. The ultrasound transmission gel (Aquasonic 100) was applied to the transducer probe, and it was placed below the chin for recording images. The multimedia microphone was used for recording the synchronized speech samples. The list of the stimuli was presented visually on the screen of the computer to the participant. Ten repetitions were collected from each subject. For statistical analysis, the Kruskal-Walli H test was administered.

3. Results and Discussion

The present study aimed to understand the articulatory dynamics of lateral /l/ and trill /r/ in Tamil and Telugu. The tongue contours of these consonants were in the VCV context. Figures 1 depicts the tongue contours and tables 2 and 3 depict the descriptive statistics of /l/ and /r/ in Tamil. On observation in the /a/ context, the posterior tongue height was more for /r/, and there was no difference in height in the mid-region and anterior region. The standard deviation decreased for /l/ as it moved towards the anterior region. The standard deviation was high in the mid-region for /r/. In the /i/ context, the posterior tongue height was more for /r/, and there was no difference in the height of the mid and anterior regions.

The standard deviation for /l/ was less in the mid-region, and for /r/, it decreased as it moved towards the anterior side. In the /u/ context, the tongue height was more for /l/, and the standard increased as it moved to the anterior region. For /r/, the standard deviation decreased as it moved towards the anterior region. For statistical analysis, the Wilcoxon signed-rank test was used. The /l/ and /r/ sounds were compared in three vowel contexts in Tamil, the results revealed that in the /a/ context, there was no significant difference in tongue advancement and tongue height. The tongue height for /l/ was more in the anterior region when compared to the /r/, but there was no significant difference in tongue advancement in the /i/context. The tongue advancement was more for /l/ in /u/ context, and the tongue height for /l/ was more in the anterior and mid-regions when compared to /r/.

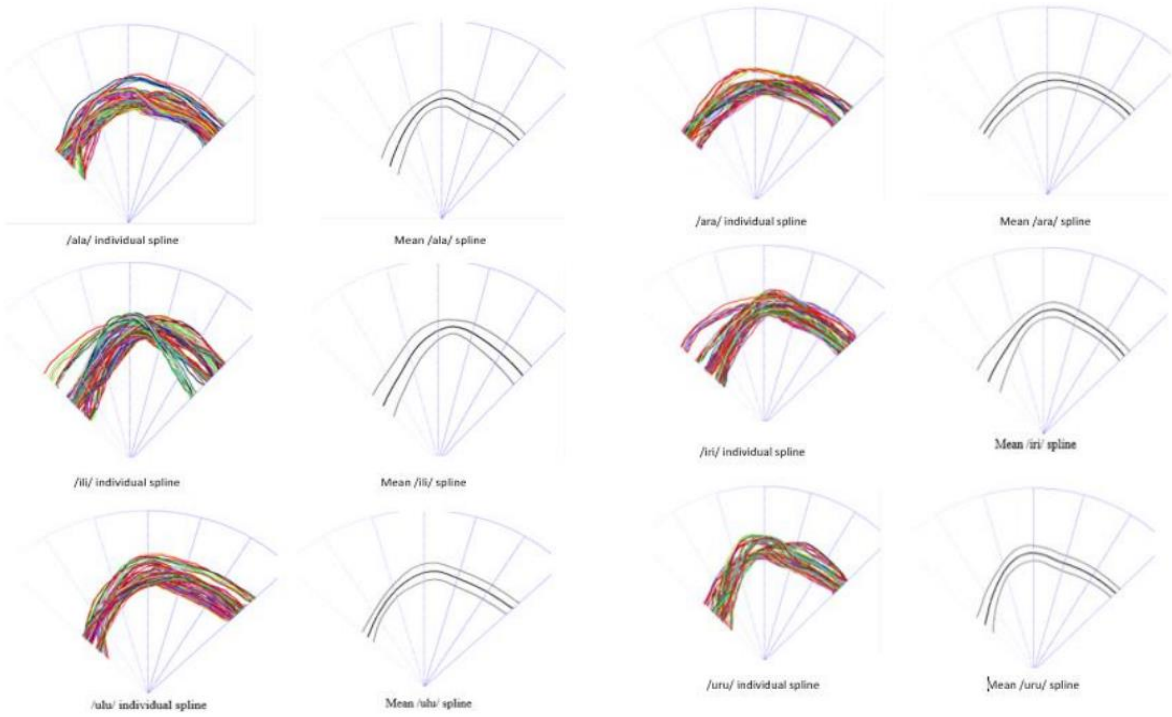

Figure 1: Tongue Contours of /l/ and /r/ in Tamil in /a/, /i/, and /u/ Contexts

This study explores the speech act of invitations in Yemeni Spoken Arabic and provides insights into the complexities of this aspect of communication. The study draws on the Speech Act Theory, which suggests that language is a type of action that follows a set of rules and these rules may vary between cultures and influence the social conventions of politeness. According to the literature review conducted for this study, previous research on invitations and speech acts has been conducted by scholars such as researchers Al-Khatib (2006), Austin (1975), Grundy (2013), Levenson (2001), Paltridge & Burton (2000), Searle & Searle (1969), Verschueren (1999), Wolfson (1989), Yule (1996). These researchers have provided valuable insights into the theoretical foundations of speech acts and invitations. The study finds that adhering to the felicity conditions of speech acts, specifically the sincerity criterion, is essential to ensure that invitations are interpreted as sincere. Yemeni Arabic speakers often use implicit utterances to express invitations, relying on shared knowledge and everyday activities to convey their intentions through broad facts and allusions. This approach to invitations is in line with the cultural and linguistic norms of the Yemeni Arabic-speaking community (Al-Hamzi et al., 2020).

Table 2. Descriptive statistics (x, y) coordinates at anterior, mid, and posterior sections of /l/ and /r/ in Tamil

	/l/				/r/			
	Mean	**Median**	**SD**	**IQR**	**Mean**	**Median**	**SD**	**IQR**
aCa anterior x	8.37	8.35	0.19	0.23	8.26	8.22	0.19	0.23
aCa anterior y	3.23	3.22	0.18	0.22	3.13	3.09	0.17	0.20
aCa mid x	5.00	5.00	0.00	0.00	5.00	5.00	0.00	0.00
aCa mid y	4.60	4.52	0.43	0.60	4.44	4.35	0.33	0.51
aCa posterior x	2.59	2.58	0.32	0.48	2.49	2.45	0.19	0.32
aCa posterior y	2.32	2.33	0.31	0.48	2.39	2.44	0.18	0.32
iCi anterior x	8.06	8.30	1.09	0.38	8.28	8.23	0.21	0.41
iCi anterior y	3.27	3.27	0.20	0.36	3.17	3.19	0.20	0.41
iCi mid x	5.00	5.00	0.00	0.00	5.00	5.00	0.00	0.00
iCi mid y	4.92	4.92	0.29	0.55	4.89	4.82	0.20	0.36
iCi posterior x	2.85	2.87	0.42	0.61	2.72	2.76	0.45	0.71
iCi posterior y	2.06	2.05	0.41	0.60	2.17	2.14	0.44	0.68
uCu anterior x	8.46	8.43	0.25	0.40	8.24	8.17	0.17	0.22
uCu anterior y	3.31	3.27	0.24	0.40	3.11	3.04	0.17	0.21
uCu mid x	5.00	5.00	0.00	0.00	5.00	5.00	0.00	0.00
uCu mid y	4.84	4.75	0.37	0.55	4.69	4.59	0.30	0.36
uCu posterior x	2.81	2.71	0.22	0.21	2.95	3.01	0.45	0.69
uCu posterior y	2.09	2.19	0.21	0.22	1.96	1.89	0.43	0.68

Table 3. /Z/ and p values at anterior, mid, and posterior sections of /l/ and /r/ in Tamil

	/Z/ value	**P value**
ara anterior x - ala anterior x	1.786	0.074
ara anterior y - ala anterior y	1.784	0.074
ara mid x - ala mid x	0.000	1.000
ara mid y – ala mid y	1.479	0.139
ara posterior x – ala posterior x	0.561	0.575
Ara posterior y – ala posterior y	0.562	0.574
iri anterior x – ili anterior x	0.866	0.386
Iri anterior y – ili anterior y	2.143	0.032
Iri mid x – ili mid x	0.000	1.000
Iri mid y – ili mid y	0.664	0.507
Iri posterior x – ili posterior x	1.378	0.168
Iri posterior y – ili posterior y	1.356	0.386
Uru anterior x – ulu anterior x	2.497	0.013
Uru anterior y – ulu anterior y	2.499	0.120
Uru mid x – ulu mid x	0.000	1.000
Uru mid y – ulu mid y	2.295	0.022
Uru posterior x – ulu posterior x	0.764	0.44
Uru posterior y – ulu posterior y	0.816	0.415

Figures 3 and 4 depict the comparison of /l/ and /r/ and tables 4 and 5 depict their descriptive statistics in Telugu. On observation of the tongue contours in the /a/ context, the overall height for /l/ was more than /r/, and the standard deviation decreased as it moved to the anterior side of the tongue contour for both sounds. In the /i/ context, the overall tongue height is more for /l/, and the standard deviation is the same across the tongue contour, but for /r/, the standard deviation decreases as it moves towards the anterior side of the tongue. For /u/, the overall tongue height is higher for /l/, and the standard deviation decreases for both as it moves toward the anterior side of the tongue contours. For statistical analysis, the Wilcoxon signed-rank test was used. It is a non-parametric test that can be used if the data doesn't meet the normality assumption and with a small sample size. The results of the statistical comparison of the tongue contours of /l/ and /r/ in the non-words /ala/ and /ara/ revealed that the tongue advancement was more for /l/ when compared to /r/. The tongue height in the anterior region was more for /l/. On comparison of the tongue contours of /l/ and /r/ in the non-words /ili/ and /iri/, the results revealed that there was no significant difference in the tongue height and tongue advancement for both sounds. On comparing the tongue contours of /l/ and /r/ in the non-words /ulu/ and /uru/, the results revealed that the tongue advancement was higher for /l/ and the tongue height in the anterior higher for /l/ when compared to /r/.

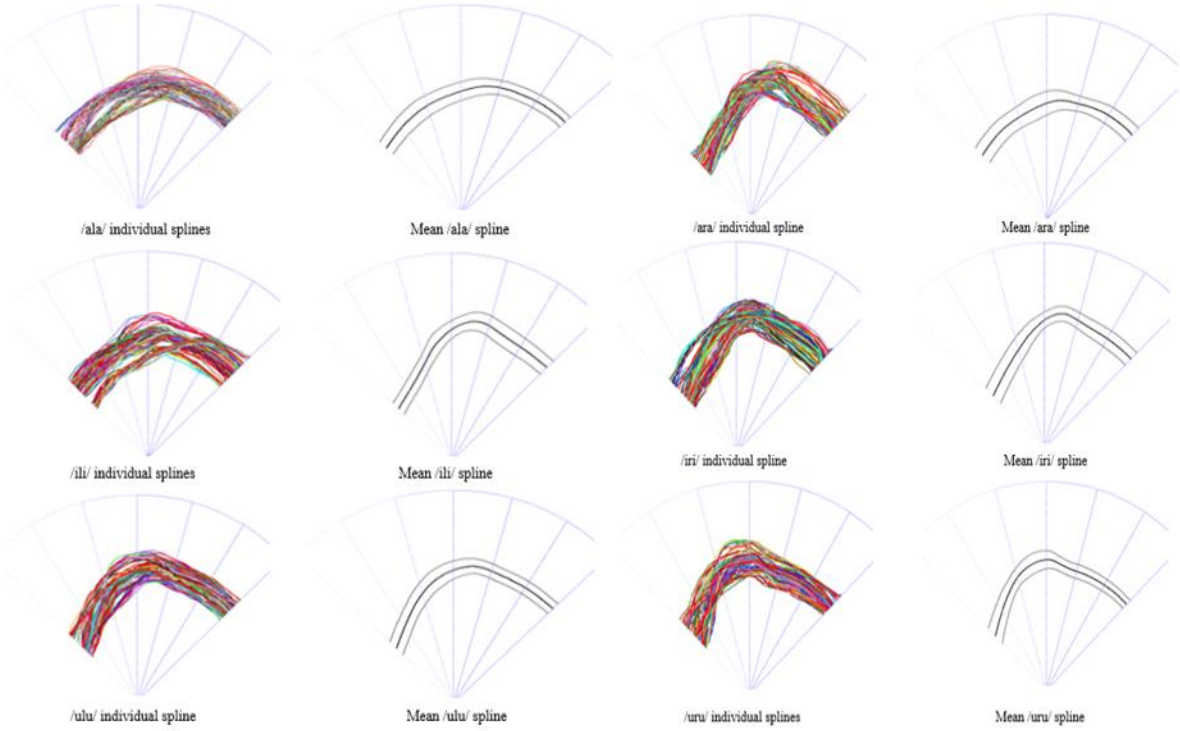

Figure 2: Tongue Contours of /l/ and /r/ in Telugu in /a/, /i/, and /u/ Contexts

On observation of /l/ and /r/ in Telugu and Tamil, the tongue height was more for /l/ in Telugu, and for /r/, it was more in Tamil in the /a/ context. In the /i/ context, posterior tongue height was higher in Tamil, and anterior height was higher in Telugu. For mid-region, no difference was found for /l/. For /r/, posterior tongue height was more elevated in Tamil, and no difference was found for the mid and anterior regions. In the /u/ context, posterior tongue height was higher in Tamil, and no difference was found for the mid and anterior regions for /l/. The tongue height was higher in Tamil for /r/.For statistical analysis, the Kruskal-Walli H test was administered. The results revealed that a significant difference was found only for three parameters among all the parameters which were /ili/ mid-tongue y-axis (/Z/= 1.097, p=0.273), /ulu/ mid-tongue y-axis(/Z/= 0.832, p=0.406) and /iri/ mid tongue y-axis (/Z/= 1.741, p=0.082).Further, Pairwise language comparisons were done using the Mann-Whitney U test as shown in Table 5.

Table 4. Descriptive statistics (x, y) coordinates at anterior, mid, and posterior sections of /l/ and /r/ in Telugu

	/l/				**/r/**			
	Mean	**Median**	**SD**	**IQR**	**Mean**	**Median**	**SD**	**IQR**
aCa anterior x	8.39	8.36	0.16	0.31	8.21	8.21	0.25	0.28
aCa anterior y	3.27	3.24	0.16	0.31	3.08	3.08	0.24	0.26
aCa mid x	5.00	5.00	0.00	0.00	5.00	5.00	0.00	0.00
aCa mid y	4.38	4.41	0.33	0.51	4.24	4.28	0.44	0.63
aCa posterior x	2.57	2.63	0.22	0.40	2.57	2.50	0.28	0.39
aCa posterior y	2.30	2.28	0.27	0.37	2.33	2.38	0.26	0.36
iCi anterior x	8.49	8.53	0.24	0.37	8.38	8.42	0.22	0.41
iCi anterior y	3.36	3.39	0.22	0.35	3.24	3.28	0.02	0.41
iCi mid x	5.00	5.00	0.00	0.00	4.99	5.00	0.00	0.00
iCi mid y	4.73	4.81	0.32	0.59	4.99	4.75	0.28	0.47
iCi posterior x	3.05	3.13	0.22	0.30	3.02	3.13	0.29	0.39
iCi posterior y	1.87	1.79	0.21	0.29	1.90	1.80	0.27	0.37
uCu anterior x	8.43	8.49	0.17	0.31	8.19	8.18	0.14	0.12
uCu anterior y	3.30	3.36	0.17	0.30	3.07	3.06	0.13	0.11
uCu mid x	4.99	5.00	0.00	0.00	5.00	5.00	0.00	0.00
uCu mid y	4.66	4.68	0.32	0.46	4.67	4.72	0.33	0.51
uCu posterior x	3.02	3.12	0.23	0.27	2.98	3.04	0.28	0.52
uCu posterior y	1.89	1.82	0.22	0.27	1.94	1.90	0.27	0.50

Table 5. /Z/ and p values at anterior, mid, and posterior sections of /l/ and /r/ in Telugu

	/Z/	**p**
ara anterior x - ala anterior x	2.705	0.007
ara anterior y - ala anterior y	2.710	0.007
ara mid x - ala mid x	1.000	0.317
ara mid y – ala mid y	1.428	0.153
ara posterior x – ala posterior x	0.357	0.721
Ara posterior y – ala posterior y	0.357	0.721
iri anterior x – ili anterior x	1.718	0.086
Iri anterior y – ili anterior y	1.718	0.086
Iri mid x – ili mid x	1.000	0.317
Iri mid y – ili mid y	0.968	0.333
Iri posterior x – ili posterior x	0.051	0.959
Iri posterior y – ili posterior y	0.072	0.521
Uru anterior x – ulu anterior x	2.803	0.005
Uru anterior y – ulu anterior y	2.803	0.005
Uru mid x – ulu mid x	1.000	0.317
Uru mid y – ulu mid y	0.359	0.317
Uru posterior x – ulu posterior x	0.153	0.878
Uru posterior y – ulu posterior y	0.153	0.878

Table 6. /Z/ and p values at mid-region across languages

	Telugu and Tamil	
	/Z/	**P**
ili mid y	1.097	0.273
ulu mid y	0.832	0.406
iri mid y	1.741	0.082

The results revealed that in Telugu, tongue advancement was slightly more for /l/ when compared to /r/ in /a/ context. The tongue height in the anterior region was slightly more for /l/. On comparison of the tongue contours of /l/ and /r/ in the /i/ context, the results revealed that there was no significant difference in the tongue height and tongue advancement for both sounds. However, in the /u/ context, the results revealed that the tongue advancement and the tongue height in the anterior region were higher for /l/ than /r/. In Tamil, the results revealed no significant difference in tongue advancement and tongue height in the /a/ context. There was no significant difference in tongue advancement, but the tongue height for /l/ was more in the anterior region when compared to the /r/ in the /i/context. The tongue advancement was more for /l/ in /u/ context, and the tongue height for /l/ was more in the anterior and mid-regions when compared to /r/.

The results for Telugu in the /a/ and /u/ contexts, and /u/ context in Tamil for tongue advancement were supported by the previous studies (Espy et al. 2001 and Stone et al.,1992), which revealed that the /l/ was produced with a more forward position when compared to /r/ and it can be because of the coarticulatory effect of vowels. However, Recasens (2011) contradicted these findings and stated that /l/ was produced with a lowered and retracted tongue dorsum in Mallorcan Catalan. The difference between the production of /l/ and /r/ might be due to specific articulatory demands and constraints of language specificity. /l/ is produced with the tongue tip touching the bottom of their front teeth, protruding slightly. In contrast, the trill /r/ sound is articulated by a rapid tapping or flapping of the tip of the tongue against the alveolar ridge. It is impossible to produce the English /r/; if the tongue tip is touching the teeth, air cannot pass over the tip (Raver-Lampman, 2017), so this might also be a reason for more advancement during the production of /l/.

The tongue height was higher for /l/ in the anterior region of the tongue for /a/ and /u/ contexts in Telugu, and /i/ and /u/ context for Tamil which was supported by a study done by Lawson, 2019, that stated the tongue tip gestures were higher for /l/ than /r/. Genioglossus activity was found to position the tongue tip against the palate (Smith, 1971), which may cause the anterior elevation of the tongue. A comparison was made for the tongue advancement and height of /l/ and /r/ across three vowels. However, a significant difference was found for the mid-region for both consonants.

4. Conclusion

The present study findings provide information regarding the tongue dynamics of trills and laterals in normal individuals across different languages. It can be used during the assessment of speech sound errors to verify the appropriateness of articulatory dynamics, specifically for /r/ and /l/, which are two common erroneous sounds. Similarly, this can be used in management by showing the typical tongue contours as references for patients with speech sound disorders. Even second language learners can use this information to differentiate the differences and similarities of these sounds across languages. The sample size in each group is less. As there is a dearth of studies on /l/ and /r/, more studies should be done to understand these speech sounds in other language families. Can be studied these sounds in meaningful words.

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