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Development of Normative Data for Motor Speech Profile in Native Gujarati Adult using CSL

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Case Report

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Abstract

Background

Motor speech function involves the coordinated control of respiratory, phonatory, and articulatory subsystems for voluntary speech production. Motor speech disorders are broadly defined as disorders resulting from neurological impairment affecting motor programming or neuromuscular execution of speech (Duffy, 1995). Computerized Speech Lab (CSL) with its Motor Speech Profile (MSP) protocol provides objective, standardized acoustic assessment of motor speech parameters including DDK rate, second formant transition, and voice and tremor characteristics. While normative data for the MSP protocol have been established in Kannada, Bengali, and Telugu-speaking adults, no such reference exists for the Gujarati-speaking population. This gap necessitates the development of language- and region-specific normative data to enable accurate clinical assessment of motor speech disorders in Gujarati-speaking individuals.

Method

Speech and Voice **s**ample was recorded using DDK Rate, Second Formant Transition and Voice & Tremor of Motor Speech Profile software from 100 native and healthy Gujarati adults aging from18 to 40 years (50 males and 50 females).

Result

The findings of the study indicates a statistically significant difference between male and female participants across all analyzed variables including DDK rate ($p = 0.0204$), second formant transition values($p = 0.0119$) and voice–tremor measures ($p = 0.0152$).

Conclusion

The present study established normative data for DDK rate, second formant transition, and voice–tremor measures of the MSP protocol in native Gujarati-speaking healthy adults. Female participants demonstrated statistically significant differences across all the protocol with respect to male. These findings provide a clinically relevant, language-specific normative reference for the objective acoustic assessment of motor speech function in the Gujarati-speaking population using CSL-MSP software.

BACKGROUND

Motor speech function is the process of coordinating the muscles of respiratory and phonatory system followed by sequencing speech to communicate.[1] For the occurrence of organized and voluntary speech, motor programming and the execution of movement of five speech modalities or sub-domains

that are respiration, phonation, resonance, articulation, and prosody; must be interacting with each other in a highly skilled and coordinated fashion.[2,3] Motor speech disorders are broadly defined as "disorder of speech resulting from neurological impairment affecting the motor programming or neuromuscular execution of speech" (Duffy, 1995).[4]

A wide variety of instrumentation have been used in the assessment of the functioning of the various components of the speech production apparatus.[5] There is dedicated computer software used for operating and assessing the instrumental acoustic measurements. Computerized Speech Lab (CSL), Praat, Dr Speech, Vagmi, and others are some of the worldwide commonly used software.[6,7] For the examination of various speech problems and research on acoustics, the potential effectiveness of CSL has been substantially validated.[8] The CSL program includes the protocol for providing the various evaluating parameters to evaluate the motor speech disorder. [6,9,10,11,12] Motor Speech Profile (MSP), Model 4500b, of Kay-Pentax, Inc., is one of them. It provides easy-to-use, built-in protocols and sophisticated analysis algorithms to produce comprehensive reports including graphic displays and numerical analysis.

MSP provides protocols for eliciting the specific speech sample, extracting the desired parameters which include DDK rate, Second formant transition, Voice characteristics and tremor features, Intonation patterns and Syllabic rate, further displaying the results of analysis in numeric and graphic formats, and generating a summary report relevant to motor disordered of speech.[13] It also complements the speech professional's well-trained ear by systematically and objectively analyzing speech parameters and correlating perceptual analysis.[6,9,10,11,12] In establishing normative data of MSP protocol of Computerized Speech Lab (CSL), studies have been conducted in native Kannada, Bengali and Telugu Speaking adults.[6,10,11] However, it is evident that there is a paucity and need for establishing normative data for the given equipment, specific to region, gender, and across age groups for MSP Protocol of CSL. Hence, an attempt was made to establish normative data in MSP protocol of Computerized Speech Lab (CSL) for Gujrati speaking adults.

METHOD

Study design

This was a cross-sectional study, conducted in the **Department of Audiology and Speech Language Pathology. The** study was designed to observe the normative values of the MSP protocol of CSL across gender and young adult.

Study setting

The study was conducted in the **sound treated Computerised Speech Lab of the Department of Audiology and Speech Language Pathology.**

Inclusion criteria

Participants with normal hearing, voice(perceptual), and oral peripheral mechanism were included.

Exclusion criteria

The participant with history of any vocal pathologies or disorders (e.g., dysphonia, laryngitis, vocal nodules), individuals with Gastroesophageal Reflux disorder (GERD) or respiratory conditions, vocal disorders, surgeries, neurological conditions like dysarthria or Apraxia and/or Aphasia or any medications that may alter voice quality (e.g., steroids) were excluded.

Sample size:

The study was conducted on a diverse group of 100 native Gujarati healthy adults including 50 male and 50 female in the age range of 18 to 40 years.

Study Duration

The study was conducted over a 6-months of period from October 2025 to March 2026.

Study Tools

KAY-PENTAX Medical, CSL Hardware, Model- 4500b and Motor Speech Profile Software Protocols of DDK rate, Second formant transition, Voice characteristics and tremor with **high-fidelity microphone** (SHURE, Cardioid Dynamic Vocal Microphone-SM48-LC-X) was used to capture clear, distortion-free voice samples.

The parameters of DDK rate were Average DDK Period (DDKavp), Average DDK Rate (DDKavr), SD of DDK Period (DDKsdp), CV of DDK Period (DDKcvp), Perturbation of DDK period (DDKjit), Average DDK Peak Intensity (DDKavi), SD of DDK Peak Intensity (DDKsdi), CV of DDK Peak Intensity (DDKcvi), Max Intensity of DDK Sample (DDKmxa), Average Intensity of DDK Sample (DDKava), and Average Syllabic Intensity (DDKsla).

Second formant transition and their respective parameters included: Magnitude of F2 Variation (f2 magn), Rate of F2 Variation (f2 rate), Regularity of F2 Variation (f2reg), Average F2 Value (f2 aver), Minimum F2 Value (F2min), Maximum F2 Value (F2max), and Fundamental Frequency (f0).

For Voice characteristics and tremor, following parameter were selected: Average Pitch Period (To), Highest Fundamental Frequency (Fhi), Lowest Fundamental Frequency (Flo), Standard Deviation of Fo (STD), Variation in Fundamental Freq.(vFo), Coefficient of Variation in Amplitude (vAm), Magnitude of Frequency Tremor (Mftr), and Magnitude of Amplitude Tremor (Matr).

Procedure

All the participants were asked to fill the consent form after going through information sheet. Each participant had undergone subjective voice analysis using GRBAS and **Oro-Peripheral Mechanism Evaluation (OPME) after completion of demographic details. Participant fulfilling the study criteria were considered for further test.**

All test tool recordings were made in a **sound treated room** to eliminate background noise and ensure high-quality recordings. The participant was instructed to remain relax and avoid any tension in the neck or throat muscles to ensure the most natural voice production.

The participant was made to seated in a stationary chair maintaining a constant posture, in front of the recording microphone at a standardized distance (8 cm) and off-axis position (45^0) from the mouth.

Once the participant was ready for the task after the voice tokens for each of the 3 tasks of computer-generated instructions was provided, the voice sample was collected by pressing the recording button for the Motor Speech Protocols i.e., DDK Rate, Second Formant Transition and Voice & Tremor.

DDK rate was recorded quickly, regularly, clearly and accurately by the repetition of /pa/ sound; for the second formant transition, the instructions was given to subject to repeat /i-u/ vowels quickly, regularly with clarity and accuracy while for individual's voice and tremor characteristics, quick, clear and accurate phonation of /a/ vowel was instructed.

Statistical Analysis

The quantitative values of the MSP protocols were documented in the excel sheet for statistical analysis.

Descriptive statistical analysis along with non-parametric statistical analysis for normality distribution, the Shapiro–Wilk test and for non normal distribution, Mann–Whitney U test were used.

RESULT

The result of the present study suggested the average age range of male is 26.8 (SD $\pm$ 5.71) years and female is 27.68 (SD $\pm$ 6.46) years.

Firstly, the result related to parameter of DDK Rate were given in Table.1

The significant differences ($p< 0.05$) were found in DDKavp, DDKavr, DDKsdp, DDKcvp, DDKjit, DDKavi, DDKmxa, DDKava, and DDKsla as shown in table-1. Male participants scored higher mean values in DDKavr, DDKavi, DDKmxa, DDKava, and DDKsla, whereas female participants showed higher values for DDKavp, DDKsdp, DDKcvp, and DDKjit.

The result of the Shapiro–Wilk and Mann–Whitney U Test scores for the normal distribution of DDK rate between male and female participants has been given in table- 2.

The result suggested that the mean DDK rate of male is 181.70 ± 30.51 milliseconds, and 211.48 ± 83.61 milliseconds is of female participants, demonstrating a higher mean value of female participants. The findings for non-normal distribution, a significant difference for both male ($W = 0.9012$, $p = 0.0018$) and female group ($W = 0.8421$, $p < 0.001$) was noted. A statistically significant difference as found between male and female participants ($U = 913.0$, $p = 0.0204$) for the intergroup comparison.

Secondly, the result regarding the Second formant Transition parameters were shown in table-3.

The result of Second Formant Transition suggested that there are significant differences ($p< 0.05$) in f2 magn, f2 rate, f2 aver, F2max, and f0 parameters except f2reg and F2min. It also suggested that female participants demonstrated higher mean values than male participants for all parameters.

The overall second formant transition variable between male and female participants as shown in table-4.

The mean of Second Formant Transition variable for male group was 15.92 ± 14.10 Hz which was comparatively lower than female participants mean value of 35.57 ± 53.77 Hz. There was a significant difference for male ($W = 0.7815$, $p < 0.001$) and female groups ($W = 0.6924$, $p < 0.001$) for non-normal distribution. The result for the intergroup comparison indicated a statistically significant difference between male and female participants ($U = 884.5$, $p = 0.0119$). Overall, the findings suggested that gender has a considerable influence on most second formant transition characteristics.

Lastly, the result for the Voice and Tremor individual parameters, revealed a statistically significant gender differences ($p< 0.05$) in To, Fhi, Flo, and STD as shown in table-5.

The statistical analysis indicated that the female participant group shows significantly higher mean values for Fhi (229.287 ± 31.611 Hz) and Flo (219.316 ± 30.574 Hz) compared to males (141.086 ± 24.653 Hz and 134.724 ± 22.764 Hz, respectively). Similarly, STD values were significantly greater in females (1.929 ± 1.126 Hz) than males (1.205 ± 0.555 Hz). In contrast, males showed significantly higher To values (7.449 ± 1.154 milliseconds) compared to females (4.586 ± 0.887 milliseconds). However, rest of the parameters are remaining nearly same in both the groups.

The Voice–Tremor protocol measures between male and female participants shown in table-6.

The average mean value of male participant group is 7.84 ± 4.99 %, whereas female participant group's mean value is 18.36 ± 23.79 %, directly indicating higher values. With the statistical findings of male ($W = 0.8563$, $p < 0.001$) and female groups ($W = 0.7318$, $p < 0.001$), a significant difference was noted for non-normal distribution in both groups. For the intergroup comparison, a statistically significant difference ($U = 897.5$, $p = 0.0152$) was found between male and female participants group.

The overall result of the present study demonstrated a gender difference across all parameters of DDK rate, Second Formant Transition, and Voice–Tremor measures with a statistically significant differences

($p < 0.05$) across all analyzed variables. The outcome of the study also suggested that the female participants demonstrated comparatively higher mean values across the analyzed parameters.

Discussion

The current study show the differences in the oral diadochokinetic (DDK) parameters—where males show higher rates and intensity for DDKavr, DDKavi, DDKmxa, DDKava, and DDKsla whereas females also demonstrate similar significant gender differences with longer, more variable, and jittered periods for DDKavp, DDKsdp, DDKcvp, and DDKjit. A significant difference ($p < 0.05$) was found in DDK parameters such as DDKavp, DDKavr, DDKsdp, DDKcvp, DDKjit, DDKavi, DDKmxa, DDKava, and DDKsla, between male and female groups. This difference in DDK parameters are primarily cause by structural and functional differences in the vocal tract, respiratory capacity, neurological and motor control.[14]

The DDKavr mean score for male (5.60 seconds) and female (5.13 seconds) of the current study are significantly correlating with other Indian study by Robin Singh, et.al[6] having mean score for male 5.85 seconds and 5.40 seconds for female in Bengali-speaking adults with significant gender differences ($p < 0.05$).

Average F_2 value ($f_2$aver) for the male (1640 Hz) and female (1880.67 Hz) of this existing study were significantly correlating with the Kannada-speaking adults study[11] having mean score for male 1675.3 Hz and 1815.7 Hz for female in the age group of 20 to 40 years.

The present study result regarding the Second Formant Transition, indicated a significant gender differences ($p < 0.05$) across f2 magn, f2 rate, f2 aver, F2max, and f0. The female participants demonstrating consistently higher mean values in second formant than males across all parameters may be biologically contributed due to their shorter vocal tract length (VTL), resulting in higher baseline resonance frequencies.[15] The differences in statistical significance for individual parameters between the two studies may partly reflect methodological variations including sample size, age range, and specific task protocols. Nonetheless, the overarching trend of higher F2-related values in females supports the existence of universal gender-based acoustic distinctions in second formant characteristics across Indian language populations.

The voice and tremor analysis of present study revealed significant gender differences ($p < 0.05$) in To, Fhi, Flo, and STD parameters. Female participants demonstrated significantly higher Fhi (229.287 Hz) and Flo (219.316 Hz) compared to males (141.086 Hz and 134.724 Hz respectively), along with a greater standard deviation of fundamental frequency (STD) in females (1.929 Hz) and males (1.205 Hz).

The mean score of vF_0 (male 0.870% & female 0.858%), Mftr (male 0.322% & female 0.304%), and Matr (male 2.051% & female 2.161%) of the current study are significantly compatible with other study by Robin Singh, et.al,[6] having mean score for vF_0 in male 1.012% & female 0.75%, Mftr in male 0.317% & female 0.312%, and Matr in male 2.551% & female 2.63% in Bengali-speaking adults.

The convergence of these findings across Gujarati and Bengali speakers reinforces that physiological differences between male and female vocal folds in mass, length, and tension are the primary drivers of fundamental frequency variation, and that these differences manifest consistently across linguistically diverse Indian populations[16] when assessed using the CSL-MSP protocol.

Limitation

This study included Gujarati-speaking adults within the age range of 18 to 40 years, which is a limitation due to the broad spectrum of dialectal and linguistic variations across Gujarat. Acoustic parameters may vary significantly between states and regions; therefore, these variations need further study. Similarly, the pediatric and geriatric age groups need to be assessed to determine variations in acoustic parameters for those demographics.

Conclusion

The present study established normative data for DDK rate, second formant transition, and voice–tremor measures of the Motor Speech Profile (MSP) protocol in native Gujarati-speaking healthy adults aged 18–40 years. Statistically significant gender differences were observed across all three analyzed variable groups (DDK rate: $p = 0.0204$; second formant transition: $p = 0.0119$; voice–tremor: $p = 0.0152$), with female participants consistently demonstrating higher mean values for frequency-related and transition magnitude parameters. The language-specific normative values established in this study provide a clinically meaningful reference for the objective assessment of motor speech function in the Gujarati-speaking population using CSL-MSP software, facilitating more accurate identification and differential diagnosis of motor speech disorders such as dysarthria and apraxia of speech. Future research should extend this normative framework to include paediatric, geriatric, and disordered populations, and should explore the influence of dialect variation within the Gujarati linguistic community on MSP parameters.

Declarations

Ethical approval and consent to participate

Prior ethical approval and clearance were taken from the Institutional Research Committee (SVIEC/ON/DASLP/BNPG24/Feb/25/06 Dated 04/02/2025). All the participants were asked to fill the consent form after going through information sheet.

Consent for publication

Written informed consent for the publication of speech and voice samples for motor speech profile protocols was taken from the participant. Identical information were removed to maintain participant privacy.

Availability of data and material

The data and related materials are available at the institute.

Competing interests

The authors declare that they have no conflict of interest.

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Self

Author's contributions

First author- Conception, Design, Supervision, Funding, Material collection, Data collection, Literature review, Writing, Critical review, Analysis and/or interpretation

Second author- Conception, Design, Supervision, Literature review, Writing, Critical review, Analysis and/or interpretation

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Tables

Table 1: DDK Parameters Between Male and Female Participants

Parameters	Unit	Male (Mean ± SD)	Female (Mean ± SD)	t-value	p-value	Interpretation
DDKavp	ms	181.70 ± 30.51	211.48 ± 83.61	-2.366	0.021	Significant
DDKavr	/s	5.60 ± 0.84	5.13 ± 1.18	2.287	0.025	
DDKsdp	ms	15.92 ± 14.10	35.57 ± 53.77	-2.500	0.015	
DDKcvp	%	7.84 ± 4.99	18.36 ± 23.79	-3.059	0.004	
DDKjit	%	1.66 ± 1.71	4.50 ± 9.00	-2.188	0.033	
DDKavi	dB	64.46 ± 4.77	61.80 ± 4.76	2.801	0.006	
DDKsdi	dB	1.16 ± 0.52	1.23 ± 0.62	-0.639	0.524	Not Significant
DDKcvi	dB	1.82 ± 0.74	1.98 ± 0.96	-0.906	0.367	
DDKmxa	dB	67.15 ± 5.01	64.45 ± 5.33	2.609	0.011	Significant
DDKava	dB	51.12 ± 4.42	48.04 ± 4.25	3.564	0.001	
DDKsla	dB	61.96 ± 3.45	60.11 ± 3.51	2.663	0.009	

Table 2: DDK Rate Between Male and Female Participants

Group	Mean ± SD	W Statistic	p-value (Normality)	U-value	p-value	Interpretation
Male	181.70 ±30.51	0.9012	0.0018	913.0	0.0204	Significant
Female	211.48 ±83.61	0.8421	<0.001			

Table 3: Second Formant Transition in individual parameters between male and female participants

Parameters	Unit	Male (Mean ± SD)	Female (Mean ± SD)	t-value	p-value	Interpretation
f2 magn	Hz	598.62 ±78.26	765.60 ± 96.15	-9.589	0.000	Significant
f2 rate	/s	1.69 ± 0.42	1.89 ± 0.52	-2.192	0.031	
f2reg	%	92.16 ± 5.49	92.57 ± 7.04	-0.328	0.744	Not Significant
f2 aver	Hz	1640± 151.63	1880.67 ± 186.71	-7.198	0.000	Significant
F2min	Hz	660.72 ± 146.02	686.23 ± 132.69	-0.913	0.363	Not Significant
F2max	Hz	2450.62± 348.85	2980.82 ± 185.77	-9.570	0.000	Significant
f0	Hz	137.63 ± 22.98	223.72 ± 30.98	-15.77	0.000	

Table 4: Second formant Transition protocol between male and female participants

Group	Mean ± SD	W Statistic	p-value (Normality)	U-value	p-value	Interpretation
Male	15.92 ± 14.10	0.7815	<0.001	884.5	0.0119	Significant
Female	35.57 ± 53.77	0.6924	<0.001			

Table 5: Voice–Tremor individual parameters between male and female participants

Parameter	Unit	Male Mean ± SD	Female Mean ± SD	t-value	p-value	Interpretation
To	ms	7.449 ± 1.154	4.586 ± 0.887	13.915	0.00	Significant
Fhi	Hz	141.086 ± 24.653	229.287 ± 31.61	-15.558	0.00	
Flo	Hz	134.724 ± 22.764	219.316 ± 30.57	-15.692	0.00	
STD	Hz	1.205 ± 0.555	1.929 ± 1.126	-4.081	0.0001	
vFo	%	0.870 ± 0.332	0.858 ± 0.445	0.145	0.8851	Not Significant
vAm	%	9.669 ± 5.024	10.063 ± 4.666	-0.407	0.6852	
Mftr	%	0.322 ± 0.102	0.304 ± 0.092	0.938	0.3506	
Matr	%	2.051 ± 0.715	2.161 ± 0.822	-0.717	0.4749	

Table 6: Voice–Tremor protocol variables between male and female participants

Group	Mean ± SD	W Statistic	p-value (Normality)	U-value	p-value	Interpretation
Male	7.84 ± 4.99	0.8563	<0.001	897.5	0.0152	Significant
Female	18.36 ± 23.79	0.7318	<0.001			