ORIGINAL ARTICLE

Normative for Motor Speech Profile in Bengali-speaking Adults

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Received on: 09 September 2022; *Accepted on:* 22 January 2023; *Published on:* 24 April 2023

Abstract

Introduction: Speech has a significant effect on the quality of life of people and contributes enormously to an individual's characteristics. Speech entails the amalgamation of numerous musculoskeletal, neuromotor, neuromuscular, and neurocognitive activities. At present, normative motor speech profiles (MSP) in the Computerized Speech Lab (CSL) for the Bengali population are not available. Hence, the current study has been undertaken to determine the normative for five parameters of the MSP for Bengali-speaking adults.

Materials and methods: The study design was cross-sectional, 100 males and females aged 18–25 years, were selected for the study. The data for the MSP was obtained as per the manufacturer's specifications.

Results: Findings indicated a significant difference for 10 parameters between males and females. Among these 10 parameters, three parameters were of diadochokinetic rate (DDK), one parameter of the second formant transition, two parameters of voice and tremor characteristics, three parameters of intonation pattern, and one parameter of syllabic rate showed differences in MSP characteristics at $p < 0.05$.

Conclusion: The results of this study offer a norm-based benchmark for MSP software in the Bengali community for those between the ages of 18 and 25.

Keywords: Diadochokinetic rate, Intonation patterns, Motor speech profile, Second formant transition, Syllabic rate, Voice characteristics.

International Journal of Phonosurgery & Laryngology (2022): 10.5005/jp-journals-10023-1239

Introduction

Speech is a unique, complex, and dynamic motor activity using which we deliver our thoughts and emotions and responses to the environment. Speech has a major impact on the quality of life of people and contributes enormously to an individual's characteristics. Speech entails the amalgamation of numerous musculoskeletal, neuromotor, neuromuscular, and neurocognitive activities. These combined and coordinated function activities lead to the production of speech. Speech motor planning, programming, control, and execution are combined actions and are referred to as motor speech processes. Disorders of motor speech processes refer to the class of speech disorders representing the inability to plan, program, and execute speech movements. These motor speech disorders involve impairment in the subdomains of speech systems, namely, respiration, phonation, articulation, and resonation.[1]

To assess these subdomains of speech, speech–language Pathologists (SLPs) undertake various perceptual and instrumental methods. Perceptual analysis continues to be the principal technique used by SLPs to examine motor speech problems. Perceptual methods are primarily grounded on the auditory-perceptual characteristics based on which SLPs perform diagnosis, differential diagnosis, a severity rating, prognosis, and critical decision-making regarding management. Although perceptual analysis stands to be a boon for the assessment and management of different speech disorders, issues like unreliability in clinicians' judgment appear to be one of the major demerits of perceptual assessment. There is a requirement for more objective examination due to the constraints, reliability, and lack of understanding between perceptual qualities and underlying speech issues.[2] Also, it becomes difficult to enumerate and directly examine the hypotheses about the pathophysiology underlying perceived speech abnormalities. Hence, instrumental assessment of speech plays a vital role in understanding and quantifying the acoustic and aerodynamic measures of speech, providing a uniform set of valid and reliable outcomes supporting the perceptual findings.

A study was done that showed instrumental analysis goes well beyond the capabilities of an auditory-based evaluation by providing quantitative and objective information on a range of speech-related variables.[3] One of the most beneficial instrumental analysis techniques that may be applied to the treatment of speech disorders is acoustic analysis (together with aerodynamic and electromyographic analysis).[4] The instrumental measurements (acoustic) are operated and assessed using dedicated computer software. Some of the commonly used software are CSL,[5,6] Praat, Dr Speech, Vaghmi, and others. There has been substantial reporting on the effectiveness of CSL for the examination of various speech problems and acoustic research reasons. Using the

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How to cite this article: Singh R, Chatterjee N, Prakash S, *et al.* Normative for Motor Speech Profile in Bengali-speaking Adults. Int J Phonosurg Laryngol 2022;12(2):31–36.

Source of support: Nil

Conflict of interest: None

CSL program's MSP software, speech parameters related to motor speech disorders are measured. One of the programs created by KayPENTAX and included in the CSL program is called MSP. It includes built-in protocols for a number of tasks for evaluating various variables, including DDK, second formant transition, voice characteristics and tremor features, intonation patterns, and syllabic rate.[5,7] The capability to repeat consonant–vowel combinations quickly, rhythmically, and with just minimal pauses is known as the DDK rate. The second formant transition procedure assesses the client's capacity for rapid and rhythmic repetition of vowel-vowel combinations. The two vowels have very different second formant positions, which require the client to change articulatory positions (i.e., tongue and lips positions). The analysis assesses the client's ability to make these transitions in a fast, rhythmic manner without vowel neutralization, thereby assessing articulatory motility. The study of voice characteristics and tremor examines vocal issues brought on by cycle-to-cycle fluctuations as well as the individuals' voice quality and tremor characteristics. The intonation stimulability protocol helps assess the client's ability to listen to an intonation pattern and repeat the "pattern"—not the pitch values. Many motor speech disorders are reflected in poor control of pitch or mono-level or monotonicity of pitch. The syllabic rate measures the client's speaking rate using the standard reading passage.

Motor speech profiles (MSP) are used to examine the entire motor speech and voice profile of people with motor speech problems such as dysarthria and apraxia of speech. This can be used for voice analysis in healthy people, voice disorders, hearing loss, etc. Although the MSP has been used to analyze speech in normal, hearing-impaired, voice-disordered, and dysarthric individuals, it is also helpful in an analyzing speech in those with motor disorders.[6,8]

Studies have been conducted on the western population to develop normative data across gender, dialects, and languages. In the Indian scenario, the normative of MSP has been undertaken in languages like Kannada in 2013[9] and is being used in clinical setups. Based on anatomical and physiological differences, individuals with normophonia vary significantly in terms of their acoustic parameters. Variations are also observed in terms of age, gender, linguistic, cultural and social situations, rate of speech, dialect, DDK, maximum phonation duration, etc. Standardization educates about the norms, simplifies the quantitative data to save time, money, and effort, and assures certification.[10] India is a country of rich cultural and linguistic diversity with changes in speech prosody and dialects within states. Therefore, normative values developed for one language cannot be used as normative for different languages. In the western population, Deliyski and Gress[5] have found that there are gender differences in a number of DDK parameters, such as the second formant transition, voice and tremor characteristics, standard syllabic rate, and intonation stimulability. They obtained information from 38 people to develop the MSP normative for participants between 18 and 61 years.

Bengali is the official state language of West Bengal (used by 86.22% population), Tripura (used by 65.73% population), and is also spoken in states like Assam (28.92%), Andaman and Nicobar Island (28.49%), Mizoram (9.83%), and Jharkhand (9.73%).[11] It is also the national language of Bangladesh. After breaking away from Bihar, West Bengal's spoken language has evolved into at least seven distinctly distinctive dialects, while Bangladesh has at least four dialects. The dialect spoken in Bengal's southeast has been designated as the language's standard conversational form, often known as Bangla.[12] This is the format typically used for formal official communication, broadcasting on radio and television. Stroke cases reported from various regions of West Bengal between January 1995 and December 2001 were retrospectively examined using hospital-based inpatient medical records (subarachnoid hemorrhage excluded).[13] There were 801 cases in all, and 792 of those had neuroimaging. A total of 399 cases of intracerebral hemorrhage and 393 cases of cerebral infarct have been reported.[13] People who have experienced a cerebral infarct frequently experience difficulty in speech, language, and overall communication skills caused by dysarthria and apraxia of speech, which has been included as speech disability under the Rights of Persons with Disabilities Act (2016) along with glossectomy, maxillofacial anomalies, laryngectomy, and bilateral vocal cord paralysis.[14] Considering the prevalence and nonavailability of language-specific norms of MSP, there is a need to establish language-specific norms for the assessment and management of neurogenic and other speech disorders.

The primary objective of our study was to attain the standardizing data for MSP in Bengali-speaking adults within the age range of 18–25 years and to obtain the gender differences for the same *via* CSL.

Materials and Methods

This cross-sectional study was conducted on 200 participants at the Speech Science Laboratory of Ali Yavar Jung National Institute of Speech and Hearing Disabilities (disabilities) [AYJNISHD (D)], Regional Centre, Kolkata, West Bengal, India, between January 2020 and March 2021. Each participant was a native Bengali speaker, and never had any speech or linguistic issues. Professional voice users were excluded from the study. The five parameters that are available in this program were studied using the MSP program under CSL software, and a normative was determined for each parameter. Prior to measurement, the participants received a standard instruction for each recording, and two practice trials were provided to ensure acquaintance with the procedure. The recording room's acoustics were adequately maintained. A total of 100 males [mean—22.1 years, standard deviation (SD)—±2.28] and 100 females (mean—21.3 years, SD—±2.12) with no communication, voice, or motor speech disorders ranging from 18 to 25-year-old were recruited for the study. Before beginning with the data collection, clearance from an otorhinolaryngologist was obtained, ascertaining that participants had no laryngeal pathology. Participants were made aware of the purpose of the study, and written consent was obtained before the administration of the test.

Procedure

Tool—MSP consisted of 25 parameters under DDK, second formant transition, voice and tremor, intonation stimulability, and standard syllabic rate were obtained using a CSL (KayPANTEX).

Instruction—the participants were requested to produce "pa" as rapidly as they could for DDK, /i-u/ as quickly as they could for the second formant transition; and /a/ as long as they could for voice and tremor characteristics. For assessing the syllabic rate, a sentence/tʃɔnd̪rima æk d̪riʃtit̪e t̪akije tʃʰilo prit̪ʰibir pane/is taken from Bengali phonetically balanced passage.[15] The intonation pattern was measured using a sentence /martʃ maʃ ki d$_3$un maʃer age aʃe/ taken from the Bengali version of Western Aphasia Battery.[16] A demonstration of the stimulus and procedure for each parameter was provided to all the participants before obtaining the data. Participants who had difficulty understanding the procedure were redemonstrated. Because the MSP software's default time window is 8 seconds, only 8 seconds of each task were logged. Each participant's whole test took place over the course of about 5–8 minutes.

Results

The findings of five parameters of MSP, that is, DDK, second formant transition, voice characteristics, tremor features, syllabic rate, and intonation pattern in running speech are reported and discussed.

Diadochokinetic Rate

The parameters scrutinized under this measure were average DDK period (DDKavp), average DDK rate (DDKavr), coefficient of variation of DDK period (DDKcvp), perturbation of DDK period (DDKjit), and coefficient of variation of DDK peak intensity (DDKcvi). The mean and SD values for the parameters of the DDK rate parameter were obtained for males and females. The mean and SD of the average DDK period (DDKavp), average DDK rate (DDKavr), coefficient of Variation of DDK Peak Intensity (DDKavi), perturbation of DDK Period (DDKjit), and coefficient of Variation of DDK period (DDKcvp) for males and females are shown in the Table 1. An independent *t*-test was employed to determine differences between males and females that suggested significant differences ($p < 0.05$) for parameters like DDKavr, DDKcvp, and DDKcvi.

Second Formant Transition

The parameters analyzed under this measure are f2 magn (magnitude of second formant variation), f2 rate (rate of second formant variation), f2reg (regularity of second formant variation), and f2 aver (average second formant value). The mean and SD values for males and females, respectively, are represented in Table 2. The comparison between mean values and standard deviation of males and females in the independent t-test for each parameter suggested a significant difference ($p < 0.05$) only in f2reg.

Voice Characteristics and Tremor

The parameters analyzed under this measure are average fundamental frequency (f0), variations in the fundamental frequency, the coefficient of variation of amplitude (vAm), the magnitude of frequency tremor (MFTR), the magnitude of amplitude tremor (MATR), the rate of frequency tremor, the rate of amplitude tremor (RATR), periodicity of frequency tremor, and periodicity of amplitude tremor (PATR). The mean (SD) values for male and female participants are mentioned in Table 3, respectively. The comparison between male and female means and SD values using an independent *t*-test for each parameter suggested significant differences in f0 and PATR ($p < 0.05$).

Intonation Pattern

The parameters to scrutinize the intonation pattern were running speech fundamental Frequency (rFo), highest fundamental frequency (rFhi), lowest fundamental frequency (rFlo), frequency variability (rVfo), and amplitude variability (rVam). The mean (SD) values for male and female participants are mentioned in Table 4, respectively. The comparison between the values of males and

Table 1: Mean and SD values of males and females for DDK

			Male		Female		
Parameter	*Name*	*Unit*	*Mean*	*SD*	*Mean*	*SD*	*p-value*
Average DDK period	DDKavp	Ms	172.9	20.21	183.62	17.209	0.11
Average DDK rate	DDKavr	/s	5.855	0.64	5.405	0.703	0.02*
Coefficient of variation of DDK period	DDKcvp	%	5.957	1.509	5.396	1.44	<0.01*
Perturbation of DDK period	DDKjit	%	1.368	0.71	1.565	0.822	0.166
Coefficient of variation of DDK peak intensity	DDKcvi	dB	1.619	0.696	2.116	0.704	0.02*

Table 2: Mean and SD values of males and females for second formant transition

		Male		Females		
Parameters	*Unit*	*Mean*	*SD*	*Mean*	*SD*	*p-value*
f2magn	Hz	560.7	58.19	577.606	64.59	0.420
f2 rate	/s	2.374	0.464	2.153	0.555	0.091
f2 reg	%	95.66	2.339	79.019	9.79	<0.01*
f2aver	Hz	1658	110.2	1584.91	188.52	0.455

Table 3: Mean and SD values of males and females for voice characteristics and tremor features

		Males		Females		
Parameters	*Unit*	*Mean*	*SD*	*Mean*	*SD*	*p-value*
Fo	Hz	141.2	20.88	243.11	16.56	<0.001*
VFo	%	1.012	0.668	0.75	0.27	0.014
VAm	%	13.36	3.246	13.42	5.74	0.766
MFTR	%	0.317	0.089	0.312	0.112	0.813
MATR	%	2.551	0.939	2.63	0.973	0.768
RATR	Hz	2.748	0.791	3.06	0.966	0.268
PATR	%	55.96	6.627	63.678	9.80	<0.001*

Table 4: Mean and SD values of males and females for intonation patterns

Parameters	*Unit*	*Males*		*Females*		*p-value*
		Mean	*SD*	*Mean*	*SD*	
rFo	Hz	165.6	19.78	264.86	18.29	<0.001*
rFhi	Hz	230.3	29.23	360.18	36.29	<0.001*
rFlo	Hz	139.8	16.41	189.22	37.61	<0.001*
rvFo	%	14.28	3.614	13.676	3.727	0.198
rvAm	%	39.47	4.135	40.922	7.114	0.347

Table 5: Mean and SD values of males and females for syllable rate

Parameter	*Unit*	*Males*		*Females*		*p-value*
		Mean	*SD*	*Mean*	*SD*	
SSrate	/s	3.757	0.83	3.3952	0.8038	0.072
SSsdur	Ms	210.11	61.01	211.8	76.037	0.851
SSpdur	Ms	134.34	40.27	160.99	58.794	0.012*
SSpau	%	40.527	11.287	36.107	15.826	0.280

females in the independent *t*-test indicated differences in rFo, rFhi, and rFlo ($p < 0.05$).

Syllabic Rate

The parameters scrutinized for syllabic rate were average syllabic rate (SSrate), average syllabic duration (SSdur), average pause duration (SSpdur), and percent pause time (SSpau). The mean (SD) values for male and female participants are mentioned in Table 5, respectively. The comparison between the values of males and females in the independent *t*-test indicated a significant difference in SSpdur ($p > 0.05$).

Discussion

Diadochokinetic rate (DDK)—at the average DDK rate, the gender differences were much larger for male speakers than for female speakers (DDKavr), and the coefficient of variation (DDKcvi) where the *p*-value was <0.05, while for the other three variables (DDKavp, DDKcvp, DDKjit, DDKcvi), although the values for the coefficient of variation of DDK period and perturbation of DDK period were found to be more for female speakers, for males and females, there was no discernible statistical difference ($p > 0.05$). For the coefficient of variation of DDK peak intensity, female values were significantly higher than the males ($p < 0.05$). The findings suggested that although there were statistical variations between males and females for different DDK rate parameters, overall, there were no or minimal differences between the two groups. Similar results were observed in a study examining the DDK in young and older Farsi-speaking individuals. The authors concluded that there was a fluctuation in the DDK rate across different age-groups, but no gender differences were found to be statistically significant ($p > 0.05$).[17]

The second formant transition—in this study, it was observed that the magnitude of f2 variation (f2magn) exhibited a greater mean in females than in males. However, this distinction lacked statistical significance ($p = 0.42 > 0.05$). For other parameters like rate of f2 variation (f2 rate), regularity of f2 variation (f2reg), and average (f2aver), greater mean values were obtained in males than in females but not statistically significant except for parameter regularity of f2 (f2reg) where $p = 0.01$ (<0.05). In a study comparing the acoustic alterations of Spanish and English vowels, it is concluded that f1 and f2 scores in English were found to be greater than those in Spanish.[18] A study conducted on the "base of articulation of 13 Indian languages" exhibited considerable gender and vowel disparities across 13 Indian languages.[19] Similar findings have also been observed in this study.

Voice characteristics and tremor—The f0 in males is found to be 141.2 Hz, and for females, 243.11 Hz. This demonstrated that the females have significantly higher fundamental frequency than the males ($p = 0.001 < 0.05$). And so was the perturbation of amplitude tremor being significantly higher perturbation in females than in males ($p = 0.001 < 0.05$). The values of the male and female participants did not significantly differ in other voice metrics ($p > 0.05$); these findings aligned with the normative study conducted on Kannada-speaking language.[9] For both male and female speakers, there is a direct correlation between the height of the vowel and the natural f0 in "transformation of formants for voice conversion using artificial neural networks."[20] f0 was highest for the vowel /u/ and lowest for the vowel /a/,[20] applied for both male and female speakers. The average f0 of female speakers is roughly 1.6 times higher than that of male speakers, which is one of the two significant variances between male and female speakers' inherent f0 of vowels and the range (maximum f0–minimum f0) over which the pitch varies for a female speaker is significantly (about three times) larger than the range for male speakers.[20] f1 and f2 were found to be higher in English compared with Spanish in a study comparing the acoustic changes in Spanish and English vowels.[18] The current study's findings also indicated variations in vowels and genders, which align with the results of a study, indicating significant differences across 13 Indian languages for vowels and genders.[19]

Intonation pattern—comparisons between males and females were performed for the different parameters of intonation pattern, namely rFo, rFhi, rFlo, rVfo, and rVam. The findings indicated that females had significantly higher rFo, rFhi, and rVfo values ($p = 0.001 < 0.05$) than the males, while the variation of frequency ($p = 0.198 > 0.05$) and amplitude ($p = 0.347 > 0.05$) were almost similar for both males and females, as depicted in Table 4. The intonation pattern plays a major role in the perception of prosodic features of voice, giving valuable information about the gender perception of the speaker along with the pitch, resonance, and quality of voice. The variation in intonation patterns of different genders may also occur in different cultures and languages. In 2018, a study was undertaken to assess intonation and gender perception and their role in transgender speakers. Listeners perceived speakers who had a higher percentage of utterances with upward intonation and a wider range of utterance semitones as female, despite there being no significant differences in the actual intonation of the four gender groups, according to an evaluation of perception differences in the intonation patterns of males, females, and transgender voices.[21]

The outcome of several studies has suggested that among the mostly extinct American Indian tribes and many societies, men and females have no difference in their way of talking, which is contradictory to the findings of the current study.[22] A gender-based analysis of intonational features in the talk show was examined, which revealed notable differences between male and female speakers' pitch accents.[23] Female speakers use a rising tone at the boundary more frequently than male speakers in declarative sentences.[23] Also, males tend to have flatter tones, while females possess more ascending and descending patterns.[23]

The syllabic rate—the mean values for parameters including the SSrate, SSdur, and SSpau exhibited no significant difference between the male and female participants. But, the SSpdur indicated that the males had a significantly higher SSpdur (p = 0.012 > 0.05) than the female. No statistically significant differences in the influence of gender were found in a pilot investigation that used tasks of spontaneous speech and reading passages to establish normative data on the speaking pace and articulation rate for the male and female speakers.[24] Differences in syllabic rate are significant in children who are developing speech and language skills. Children's word perception varied depending on the speaker's gender and the amount of syllables in each word, with 3-year-old having a lower word perception than 5–6 years old.[25] Words uttered by the female speaker were perceived more favorably than those uttered by the male speaker, while polysyllabic words were perceived more favorably than monosyllabic ones.[25]

Due to the sufficiently high sample size (n = 200), the results of this study may be applied to all age-groups from 18 to 25 years. To gather statistics for MSP for the entire Bengali population, the remaining age categories must also be examined on the same platform. Additionally, no visual assessment of the vocal folds was done in this investigation to determine whether they were healthy.

Future studies can focus on obtaining the values for the disordered population, the pediatric population, and the geriatric population considering the other limitations of the current study.

Conclusion

Many studies have found that ethnicity, gender, age, and social class are some of the primary sociological factors that affect speech, and therefore it is important to get language-specific standards for reference. In order to effectively use the MSP as an objective instrument, normative data must be established in the Bengali-speaking community. The results of this study may have clinical implications for the thorough assessment of the community of people with neurological problems between the ages of 18 and 25. The obtained data may help in a more sensitive and specific diagnosis of motor speech disorders and can also be used in research specifically for the Bengali population, providing more explicit and improved accuracy.

Acknowledgment

I appreciate having the opportunity to collaborate on this project with everyone. Each member has given me a great deal of professional and personal advice and has taught me a lot about both scientific research and everyday life. I want to thank the director of AYJNISHD (D), Mumbai, and the assistant director of AYJNISHD (D), RC, Kolkata, in particular, for their encouragement and assistance.

Declarations

Ethical approval—Institutional Ethical Committee has approved the research.

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