Speech Motor Control in Children with Downs Syndrome: Evidences from Formant Centralization Ratio

Radish Kumar Balasubramanium*, Vibha Kanagokar, N.M. Sreya and Jayashree S. Bhat

Department of Audiology and Speech Language Pathology, Kasturba Medical College (Manipal University), Mangalore, India

Abstract: *Introduction*: Studies have highlighted the sensitivity of Formant centralization ratio (FCR) in the identification of vowel centralization. Since children with Downs Syndrome (DS) are found to exhibit imprecise articulation, the present study aimed at evaluating whether children with DS exhibit vowel centralization using FCR.

Method: The study included 30 children with Downs syndrome and 30 healthy age and gender matched controls in the age range of 6-8 years. Materials consisted of 9 words with three vowels (/i/, /u/, and /a/) in the initial, medial, and the final word positions respectively. First and second formant frequency values were extracted using PRAAT software. The vowel-formant data (e.g., frequency of F1, F2 etc.) were separately averaged for each child and then the FCR was constructed from these averages using the formula (F2u+F2a+F1i+F1u) / (F2i+F1a). Independent t-test was employed to find out the significance of difference between the means of the two groups.

Results: The results of Independent t-test revealed significant difference between the mean FCR of both the groups at t= 8.535, $p < 0.00$ indicating higher FCR values in children with Downs syndrome in comparison to typically developing peers.

Conclusion: The results of the present study indicated that FCR obtained from both the groups vary significantly, thereby indicating that the vowel production in children with Downs syndrome may be subjected to vowel centralization. The present findings suggest the potential abilities of FCR metric in identifying vowel errors without characterizing the nature of vowel abnormalities and hence this metric should be used in the clinical population with caution.

Keywords: Formant centralization ratio, Speech motor control, Downs syndrome, Vowel centralization.

INTRODUCTION

Down syndrome (DS) is the most frequently occurring genetic disorder [1]. Several studies have documented the speech characteristics in children with Down's syndrome, with the major emphasis on consonant production [2-13]. However, very few studies have documented the vowel characteristics in children with Down's syndrome [14,15]. These studies on vowel characteristics have reported that vowel errors were within the top six articulatory errors in children with Down's syndrome.

Conventionally, articulation tests have been used to represent the articulatory abnormalities in the production of vowels. However, Vowel space area (VSA) has been objectively used to signify vowel errors [16,17]. VSA is based on the formant frequencies of different corner vowels and is reported to be extremely reliable. Few studies have used the formant frequency data to compare individuals with DS and normal controls. One such study is by Moran who compared adults with and without DS. Results revealed that there were no significant differences in the formant frequencies between the groups and there were no indications of resonance differences [18]. Moura *et al*. used the F2i/F2u ratio to compare voice of DS children with that of controls and found that the ratio could differentiate the speech motor control abilities of children with DS from that of controls[1].

Bunton & Leddy evaluated acoustic vowel space area and articulatory working space for two adults with DS who had reduced speech intelligibility (mean= 56%) based on single words. They collected data using a real-time flesh-point tracking method using X-ray microbeam. Their results showed smaller F1-F2 acoustic vowel space area for both speakers with DS when compared to the controls. The study also reported reduced articulatory working space area and slower movement speed for three of the four tongue points analysed. These tools have reported abnormal vowel articulations but could not reliably indicate vowel centralization. Also these tools have the disadvantage of inter and intra speaker variability [19].

In this regard, Sapir *et al.* gave a metric known as FCR, which has been designed to decrease the sensitivity to inter and intra-speaker variability and enhance sensitivity to vowel centralization [20]. Sapir, Ramig, Spielman, and Fox compared the FCR values of men, women and children from the formant data given by Hillenbrand, Getty, Clark, & Wheeler [21], and concluded the normal FCR value to be approximately 1.0 at least for speakers of American English.These investigators have further verified the utility of FCR by comparing healthy speakers to the speakers with the

*Address correspondence to this author at the Department of Audiology and Speech Language Pathology, Kasturba Medical College (Manipal University), Mangalore, India; Tel: +919964585508; E-mail: radheesh_b@yahoo.co.in

E-ISSN: 2311-1917/15

diagnosis of either Parkinson's disease, traumatic brain injury or muscle tension dysphonia. The results indicated greater sensitivity of the FCR to abnormal vowel articulation than the VSA [22]. The presence of vowel errors in children with Downs syndrome represents the speech motor control deficits in this population. These speech motor control deficits pertaining to vowel errors are least investigated in the literature. In the present study, the same was investigated using a sensitive metric FCR. Since FCR relates to the identification of vowel centralization, speech motor control deficits pertaining to vowel production can be identified. Hence, the present study was planned in this direction.

Aim of the Study

To investigate the speech motor control abilities in the production of vowels in children with Downs syndrome using Formant Centralization Ratio.

METHOD

The study followed the case control design and was approved by the Institutional review committee and Institutional human research ethics committee at Kasturba Medical College, Mangalore, India.

Participants

The study included 30 children with Downs syndrome (16 males, 14 females) and 30 healthy age and gender matched controls in the age range of 6-8 years. The diagnosis of Downs syndrome was made by an experienced paediatrician based on the observable physical symptoms. All the children with Downs syndrome were verbal and their mean language age was 3.0 years as assessed through Assessment of Language Development (ALD) [23] by an experienced speech language pathologists. The exclusion criteria considered for the control group children were those with the speech language and neurological disabilities. Children with hearing impairment was excluded in both the group of participants through Hearing screening at 25 dB HL for the frequencies of 500Hz, 1 KHz, 2 KHz, and 4KHz. There were no dysfluencies observed in both group of participants. All the participants in both group were native speakers of Kannada language. Informed consent was obtained from the parents of children in both the groups.

Materials

Materials consisted of 9 bisyllabic words with three vowels (/i/, /u/, and /a/) in the initial, medial, and the final word positions respectively. These words were selected on the basis of vocabulary familiar to all the participants. These nine words were presented through pictures and the participants were expected to repeat the carrier phrase (idu …..) and name the picture. The words used were *amma, kannu, u:ta, ili, gini, topi, u:ta, huli* and *ka:lu.*

Instrumentation

Recording was done through a sensitive Peltor microphone connected to the acer laptop in a quiet room. Praat software (version 5.1.43) was used for the recording and sampling frequency was set at 44100 Hz.

Procedure

Participants were seated on a comfortable chair. They were instructed to identify the picture and name using carrier phrase. Each phrase was repeated by the participant 3 times. The recordings were obtained using a head mounted condenser microphone positioned 10 cm from the lips connected to the laptop provided with the PRAAT software for formant analysis. These recordings were obtained within the home premises in a relatively noise free environment.

Analysis

Regardless of the number of trials, all the targeted vowels were extracted and F1 and F2 values were measured. The vowel-formant data were separately averaged for each child. The FCR was then constructed from these averages using the formula (F2u+F2a+F1i+F1u) / (F2i+F1a). Independent t-test was employed to find out the significance of difference between the means of the two groups.

RESULTS

The present study investigated the speech motor control abilities in children with Downs syndrome using formant centralization ratio. Descriptive statistics was employed to find out the mean and standard deviation and the results are shown in Table **1**.

Table 1: Mean and Standard Deviation of FCR in Clinical & Control Group

Groups	Mean	Standard Deviation
Clinical group	1.5413	0.178
Control group	1.2037	0.123

From the table, it is observed that FCR is higher in children with Downs syndrome in comparison to normal controls indicating the vowel abnormalities in children with DS.

The results of Independent t-test also revealed significant difference between the mean FCR of both the groups at t= 8.535, $p < 0.00$ indicating significantly higher FCR values in children with DS in comparison to typically developing peers. These higher FCR values suggest the deviated vowel production in children with DS.

DISCUSSION

As children with Downs syndrome exhibit articulation errors, there is a need to investigate specific aspects of speech motor control in them. In the present study, speech motor control required for vowel production is targeted. In the past, vowel space area and F2i/F2u ratio have been used as a tool in the investigation of vowel abnormalities of children with Downs syndrome. However, each of these metric had limitations in terms of inter and intra subject variability. Hence, Sapir *et al.* (2008) proposed a metric known as the FCR, and reported this ratio to reduce sensitivity to inter-speaker variability and enhance sensitivity to vowel centralization [20]. Hence, the present study used FCR to determine if vowel production in children with Downs syndrome matched the controls. The results of the present study revealed that there was a significant difference between the means of both the groups indicating that the vowels produced by children with Downs syndrome were deviant from that of typically developing children.

These deviated formant centralization ratio presents as vowel reduction in children with Downs syndrome. Factors contributing to the deviated formant centralization ratio could be the differences in the anatomical structures (Midface hypoplasia, reduced bone growth in the regions of heand and face etc). This would affect the placement of articulation during vowel production thereby preventing them from making précise articulatory movements [24]. Variations in the oral, and pharyngeal cavities (reduced oral cavity size, high palatal arch) in these children with Downs syndrome also affects the way in which the sound travels through these resonating cavities [25-27]. All these reasons would have affected the formant frequencies and hence the results of the present study.

In addition, physiological differences might have also contributed to the deviations in the formant centralization ratio. These physiological differences include abnormal oromotor skills and/or oromotor planning and programming abilities [15]. In this regard, Sapir *et al*. also claims that reduced anterior to posterior direction and restricted movement of the lips can increase the formant centralization ratio [22] and hence the results of the present study. These findings reflect reduced speech motor control abilities in children with Downs syndrome when compared to normal controls. These findings are in consonance with the previous studies indicating reduced articulatory working space area and slower movement speed in children with Downs syndrome when compared to normals [15,19].

The performance of these two groups suggests that they reflected different articulatory patterns indicating speech motor control deficits in children with Downs syndrome. It is also observed that vowel distortions were predominant in many of these children with downs syndrome. Some of these distortions take the form of central shwua vowel. However, it is not observed in all the children with Downs syndrome. Hence, it is not clear what exactly are represented by the FCR, and how those can be related to perceptual speech deviancies in particularly vowel errors. This raises the reliability of formant centralization ratio in the identification of vowel centralization. It is therefore necessary to correlate the values of FCR with perceptual, physiological and kinematic measurements of vowel articulation in the future studies which would shed some light on the nature of vowel errors depicted by FCR. Moreover, in this study, FCR was tested with the vowels /i/, /u/, and /a/. It is also recommended to check the reliability of this metric with different vowels and with different speech tasks, phonetic environment and severity of abnormal articulation. Further gender issues should be taken into consideration in the future studies.

CONCLUSION

The present study investigated the FCR in children with Downs syndrome and typically developing children in the age range 6-8 years. The results indicated that the FCR obtained from both the groups vary significantly, thereby indicating that the vowel production in children with Downs syndrome may be subjected to vowel centralization suggesting speech motor control deficits in children with Downs syndrome. The present findings suggest the potential abilities of FCR metric in identifying vowel errors without characterizing the nature of vowel abnormalities and hence this metric should be used in the clinical population with caution.

REFERENCES

[1] Moura C, Cunha L, Vilarinho H, et al. Voice parameters in children with Down syndrome. J Voice 2008; 22: 34-42. http://dx.doi.org/10.1016/j.jvoice.2006.08.011

[2] Pentz AL. Formant amplitude of children with Down's syndrome. Am J Ment Defic 1987; 92: 230-3.

[3] Swift E, Rosin M. Remediation sequence to improve speech intelligibility for students with Down syndrome. Lang, Speech Hear Ser Sch 1990; 21: 140-6. http://dx.doi.org/10.1044/0161-1461.2103.140

[4] Kumin L. Intelligibility of speech in children with Down syndrome in natural settings: parent's perspective. Percept Mot Skills 1994; 78: 307-13. http://dx.doi.org/10.2466/pms.1994.78.1.307

[5] Kumin L. Speech intelligibility and childhood verbal apraxia in children with Down syndrome. Down Syndr Res Pract 2006; 10: 10-22. http://dx.doi.org/10.3104/reports.301

[6] Kumin L. Maximizing speech and language in children and adolescents withDown syndrome. In: Cohen W, Nadel L, Madnick M, Editors. Down syndrome: Visions for the 21st century. New York: Wiley-Liss; 2002a.

[7] Kumin L. Why can't you understand what I am saying: speech intelligibility in daily life. Disability Solutions 2002b; 5: 1-15.

[8] Heselwood B, Bray M, Crookston I. Juncture, rhythm, and planning in the speech of adults with Down's syndrome. Clin Linguist Phon 1995; 9: 121-137. http://dx.doi.org/10.3109/02699209508985328

[9] Chapman R, Sueng H, Schwartz A, Kay-Raining Bird, A. Language skills of children and adolescents with Down syndrome: II production deficits. J Speech Lang Hear Res 1998; 41: 861-873. http://dx.doi.org/10.1044/jslhr.4104.861

[10] Miller J, Leddy, M. Down syndrome: the impact of speech production on language development. In: Paul R, Editor. Communication and language intervention series: Vol. 8. Exploring the speech-language connection. Baltimore: Paul H. Brookes Publishing Co; 1998.

[11] Rosin M, Swift E. Communication intervention: improving the speech intelligibility of children with Down syndrome. In: Miller J, Leddy M, Leavitt L, Editors. Improving the communication of people with Down syndrome (pp. 133-160). Baltimore, MD: Paul H. Brookes Publishing Co: 1999.

[12] Chapman R, Hesketh L. Behavioral phenotype of individuals with Down syndrome. Ment Retard Dev Disabil Res Rev 2000: 6: 84-95. http://dx.doi.org/10.1002/1098-2779(2000)6:2<84::AID-MRDD2>3.0.CO;2-P

[13] Stoel-Gammon C. Down syndrome phonology: developmental patterns and intervention strategies. Down Syndr Res Pract 2001; 7: 93-100. http://dx.doi.org/10.3104/reviews.118

[14] Van Borsel J. Articulation in Down's syndrome adolescents and adults. Eur J Disord Commun 1996: 31: 415-44. http://dx.doi.org/10.3109/13682829609031330

[15] Bunton K, Leddy M, Miller J. Phonetic intelligibility testing in adults with Down Syndrome. Down Syndr Res Pract 2009: 12: 144-54.

[16] Turner G, Tjaden K, Weismer G. The influence of speaking rate on vowel space and intelligibility for individuals with amyotrophic lateral sclerosis. J Speech Hear Res 1995; 38: 1001-13. http://dx.doi.org/10.1044/jshr.3805.1001

[17] Weismer G, Laures J, Jeng J-Y, Kent R, Kent J. Effect of speaking rate manipulations on acoustic and perceptual aspects of the dysarthria in amyotrophic lateral sclerosis. Folia Phoniat logop 2000; 52: 201-19. http://dx.doi.org/10.1159/000021536

[18] Moran M. Identification of Down's syndrome adults from prolonged vowel samples. J Commun Disord 1986; 19: 387-94. http://dx.doi.org/10.1016/0021-9924(86)90028-6

[19] Bunton K, Leddy M. An evaluation of articulatory working space area in vowel production of adults with Downs syndrome. Clin Linguist Phon 2011; 25: 321-34. http://dx.doi.org/10.3109/02699206.2010.535647

[20] Sapir S, et al. Formant centralization ratio (FCR) as a sensitive metric of vowel undershoot: Comparison with vowel space area (VSA) in impaired versus healthy speakers. PLM2008 Abstract 2008; Retrieved from http: //ifa.amu.edu.pl/plm/.

[21] Hillenbrand J, Getty L, Clark M, Wheeler K. Acoustic characteristics of American English vowels. J Acoust Soc Am 1995; 97: 3099-111. http://dx.doi.org/10.1121/1.411872

[22] Sapir S, Ramig LO, Spielman JL, Fox C. Formant Centralization Ratio (FCR): A proposal for a new acoustic measure of dysarthric speech. J speech lang hear res 2010; 53: 114-34. http://dx.doi.org/10.1044/1092-4388(2009/08-0184)

[23] Lakkana S, Venkatesh K, Bhat JS. Assessment of language development 2007. Mangalore: Codeword Publishers.

[24] Rosin M, Swift E, Bless D, Vetter D. Communication profiles of adolescents with Down syndrome. Journal of Childhood Communication Disorders 1998; 12: 49-64. http://dx.doi.org/10.1177/152574018801200105

[25] Redman R, Shapiro B, Gorlin R. Measurement of normal and reportedly malformed palatal vaults: III. Down's syndrome (trisomy 21, Mongolism). J Pediatr 1965; 67: 162-165. http://dx.doi.org/10.1016/S0022-3476(65)80238-4

[26] Ardran G, Harker P, Kemp F. Tongue size in Down syndrome. J Ment Defic Res 1972; 16: 160-6.

[27] Borghi R. Consonant phoneme and distinctive feature error patterns in speech. In: Van Dyke D, Lang D, Heide F, van Duyne S, Soucek M, Editors. Clinical perspectives in the management of Down syndrome. New York: Springer; 1990. http://dx.doi.org/10.1007/978-1-4613-9644-4_12

Received on 12-12-2014 Accepted on 10-02-2015 Published on 30-04-2015

DOI: http://dx.doi.org/10.12970/2311-1917.2015.03.01.4