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Voice Onset Time of Stop Consonants in Hindi Speaking Children with Cerebral Palsy

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Abstract: ***The current study was conducted for children with CP who are Hindi speakers, to analyze voice onset time (VOT) patterns associated with stop consonants. The purpose was to gain more detailed insights into how the coordination and timing needed for these articulations may be affected by the neurodevelopmental disorder ultimately opening up avenues for improved treatment solutions. Total 20 children in the age group of 6 - 8 years were taken for the study which was divided into two groups: 10 children diagnosed with spastic CP and 10 typical children speaking Hindi. Measuring VOT through voice analysis helped us gauge the interval lapsing between releasing a stop closure and voicing onset. The outcomes exhibited considerable variation in VOT values when comparing groups of children with cerebral palsy (CP) against typical children speaking Hindi. Specifically, CP children showed longer VOT durations indicating delayed voicing onset compared to controls. These findings point out that children who have cerebral palsy exhibit different timing and coordination patterns upon pronouncing stop consonants. It is essential to grasp the VOT traits in children with cerebral palsy. This will aid in creating suitable intervention techniques that enhance their speech comprehensibility and communication skills.***

Keywords: Cerebral palsy, Voice onset time, Hindi language, typical children

1. Introduction

Cerebral palsy (CP) is a neurodevelopmental disorder in which individuals experience conditions such as impaired muscle tone, mobility challenges and motor skill difficulties due to developmental brain injuries. Recognizable signs may appear earlier in life but the manifestation of this condition can evolve over time - it is usually diagnosed between ages 3 - 5 years old or later. Neurological rehabilitation is essential when addressing conditions caused by muscle tone abnormalities while developing physical rehabilitation therapies along with occupational therapy for individuals affected by CP are also crucial areas to consider during treatment. Additionally, people who have been diagnosed with CP might struggle with other related health co - morbidities such as epilepsy seizures episodes or cognitive impairment problems and gastrointestinal function disturbances. The interdisciplinary nature of the treatment required means - treating physicians must collaborate alongside experienced teams composed of neurologists, orthopedic, psychological, social care specialists and speech language pathologists in order to manage the condition more effectively (Gulati & Sondhi 2018).

To improve patient autonomy multidisciplinary teams should be selected while keeping individual patient needs in mind. The aim should beto developregularly updated global treatment care plans. Cerebral palsy impacts several vital areas such as sensory capabilities, movement abilities and cognitive function contributing majorly to verbal expression challenges such as speech, language and communication. Successful intervention from professional speech - language therapists can mitigate the impact of these challenges.

Communication difficulties can arise when the neuromuscular regulation of the speech mechanism is disrupted. This issue frequently results in poor speech output among patients with CP. Sadly, a large proportion (about 38%) of children with CP experience impaired speech functions such as articulation difficulties (Sankar & Mundkur, 2005). These problems can greatly impact intelligibility which can limit participation in various important activities like work or school. Ultimately these constraints significantly reduce the quality of life experienced by these individuals. Children diagnosed with spastic cerebral palsy most commonly experience varying degrees of dysarthria - one key symptom being the imprecise manner of articulation. Inaccurate articulatory position and manner of consonants are two very consistent aspects of CP dysarthria (Platt, Andrews, Young & Quinn, 1980).

2. Review of Literature

Complete closure within our vocal tracts creates certain speech sounds called stop consonants. The pressure built up inside must then be rapidly released - creating a burst - like effect. Stop consonants make up nearly a third (29%) of all consonants used in human language and are a valuable component in communication from any age (Kent & Kim, 2008). In addition to indicating speech intelligibility, stops also highlight the effective coordination between laryngeal and supra - laryngeal level mechanisms (Auzou, Ozsancak, Morris, Jan, Eustache &Hannequin, 2000). To enhance therapy and differential diagnosis approaches while better understanding speech intelligibility deficits, it is crucial to grasp the abnormal pattern of stop consonants. Taking into account the potential impact of stop consonant production on speech intelligibility adds weight to this importance (Kay, 2012).

Extensive research has focused on understanding stop consonants within normal and disordered speech patterns alike. Various acoustic features associated with these sounds are under investigation including stop gap, stop burst, formant transitions and voice onset time (VOT) which has proven valuable for distinguishing subtypes of dysarthria as

well as exploring connections between VOT values and overall speech intelligibility. VOT refers to the length of time that passes between the release of a plosive and the onset of vibration in the vocal folds; measured in milliseconds (Rezaei & Salehi, 2006). Researchers note that individuals with dysarthria exhibit differing characteristics regarding their VOT depending on factors such as underlying cause or specific type; however clear associations between irregularities in VOT levels specifically and reduced speech intelligibility remain elusive. Ansel and Kent (1992) analysis did not find any significant link between VOT and intelligibility scores amongst individuals with cerebral palsy. In contrast, another investigation involving Mandarin speakers who also had cerebral palsy found that VOT variation played a crucial role in predicting their level of intelligibility (Liu, Tseng & Tsao, 2000).

Singh & Tiwari (2016) said that Hindi language encompasses a range of non - nasal stops such as velar, palatal, retroflex, dental and bilabial equivalents pronounced at varying levels of intensity: voiceless unaspirated or aspirated; voiced unaspirated or aspirated; as well as nasal flavours. They also demonstrated that most forms of non - nasal stops could be generated through the combination of relatively simple acoustic functions. Pyata&Banik (2016) studied the phonological development profile in typical children speaking Hindi and found that all the stop sounds were achieved in initial, medial & final position in words by the age of 5 ½ years. Therefore, the age range selected for the present study was 6 - 8 years.

Despite the use of both acoustic and spectral analysis in earlier studies on stops and other consonants across several foreign languages, there is limited published literature detailing acoustics involved with stop consonants among normal/disordered populations within Indian Languages where our research aims to contribute meaningfully.

Samudravijaya (2003) studied durational characteristics of Hindi stop consonants and found that the post - release duration of a plosive changes systematically with manner of articulation. However, due to its large variation in continuous speech, the post - release duration alone is not sufficient to identify the manner of articulation of the stop. A low value of the ratio of the duration of the vowel to the closure duration of the following plosive is a cue for gemination in Hindi stop consonants in continuous speech.

Joy & Sreedevi (2019) studied temporal characteristics of stop consonants in pediatric cochlear implant users. They used PRAAT software to derive the acoustic measures – Voice Onset Time (VOT), Burst duration and Closure duration. The results of the study revealed that children using CI differed significantly from TDC for a few target consonants in burst duration and closure duration. However, VOT did not show any significant difference between children using CI and TDC.
Jeong, Kim, Sim & Park (2011) studied the maximum phonation time (MPT) and temporal aspects in Korean stops in children with spastic cerebral palsy and the results were as follows: 1) The MPTs of the cerebral palsy (CP) groups, both Group I and Group II, were significantly shorter than those of the normal group.2) The closure durations of the two CP groups were longer than those of the normal group for all 9 target syllables.3) The aspiration durations of the two CP groups were longer than those of the normal group.4) The closure duration of the normal and CP Group I was significantly different among tense, aspirated and lax. However, the CP Group II was different from normal.5) The aspiration duration of the normal and CP Group I was significantly different among aspirated, tense and lax. However, the CP Group II was different from normal.6) The place of articulation influenced less than the manner of articulation on closure and aspiration duration.

Kim& Kim (2019) did acoustic analysis of Korean stop sounds in patients with dysarthria and resulted that the dysarthria group (DG) had longer closure durations, suggesting slower articulatory movements of the DG than the normal control group (NC). They further concluded that the DG has centralized tongue positions, they control the tenseness and the timing coordination between laryngeal and supra - laryngeal articulators to distinctively produce different types of phonation of stops.

3. Methodology

The objective of this study was to analyze the voice onset time of stop consonants in children with cerebral palsy who are native Hindi speakers.

Participants:
The present study included total 20 participants, out of which 10 were diagnosed with spastic cerebral palsy (CP) and 10 were typical children speaking Hindi (TD). The participants in both groups were further subdivided into two groups based on their chronological age i. e., 6.0 - 6.11 years and 7.0 - 7.11 years. Children with any type of CP other than spastic and with any associated problems like mental retardation were excluded from the study.

Procedure:
In order to study the VOT of stop consonants, PRAAT software was used to record and analyze the voice samples of each child. Total 5non - nasal voiced unaspiratedstop consonants of Hindi language were used as stimulus - bilabial (/b/), dental (/d̪/), retroflex (/ɖ/), palatal (/ɟ/) and velar (/g/). The production of the stops was recorded for all 20 participants in a quiet room with no background noise. The recorded voice samples were subjected to detailed analysis to get the VOT for each group of participants.

Data Analysis:
The VOT for each participant was obtained using PRAAT software. The values were tabulated separately for the CP & TD group with respect to the two age groups. Descriptive statistical analysis was thus carried out within the groups and across the groups to obtain the comparative values of VOT of stop consonants in CP & TD children.

4. Results

The obtained data was statistically analysed and the results are discussed below.

Table 1: Showing comparison of mean voice onset time of typical children within the group

VOT of TD within group (in seconds)						
S. NO.	Consonant	6.0 - 6.11 yrs		7.0 - 7.11 yrs		p value
		Mean	SD	Mean	SD	
1	Bilabial /b/	0.260	0.054	0.255	0.018	0.850
2	Dental /d̪/	0.361	0.121	0.229	0.033	0.048
3	Retroflex /ɖ/	0.261	0.063	0.259	0.020	0.963
4	Palatal /ɟ/	0.316	0.103	0.284	0.023	0.512
5	Velar /g/	0.291	0.080	0.243	0.027	0.242

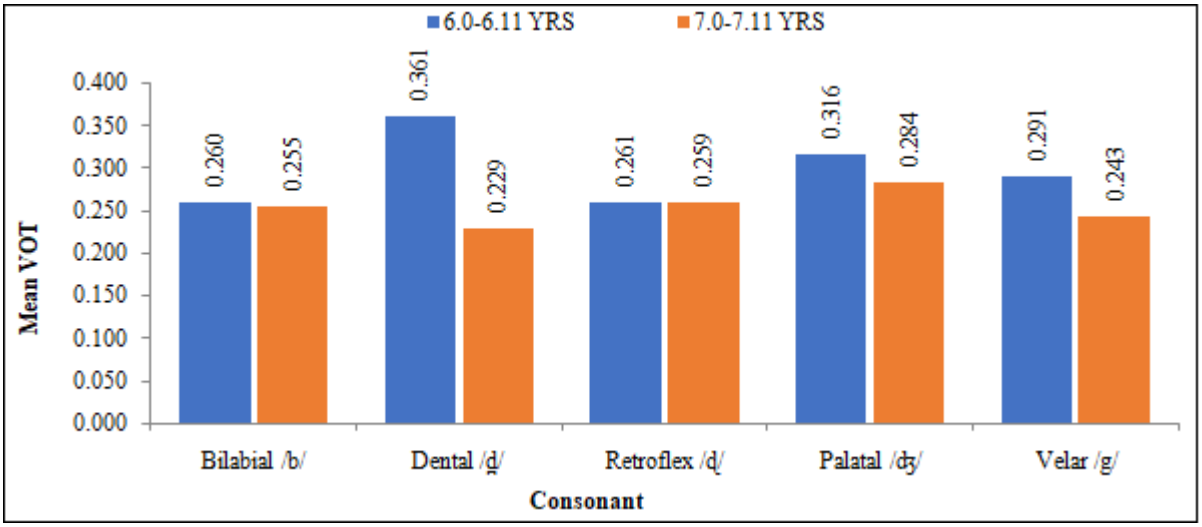

Figure 1: Showing comparison of mean voice onset time of typical children within the group

The comparative values of mean voice onset time of typical children within the group showed significant difference for dental stop consonant /d̪/.

Table 2: Showing comparison of mean voice onset time of CP children within the group

VOT of CP within group (in seconds)						
S. NO.	Consonant	6.0 - 6.11 yrs		7.0 - 7.11 yrs		p value
		Mean	SD	Mean	SD	
1	Bilabial /b/	0.348	0.083	0.382	0.086	0.551
2	Dental /d̪/	0.407	0.110	0.438	0.051	0.582
3	Retroflex /ɖ/	0.428	0.092	0.441	0.051	0.799
4	Palatal /ɟ/	0.434	0.050	0.466	0.035	0.276
5	Velar /g/	0.332	0.068	0.363	0.062	0.471

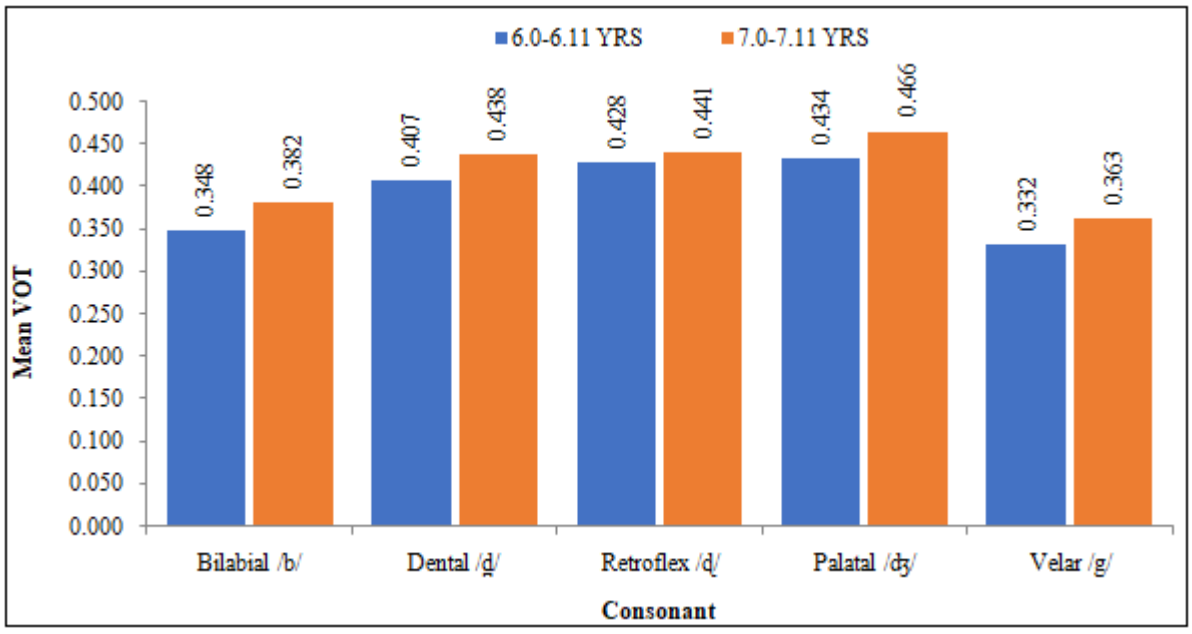

Figure 2: Showing comparison of mean voice onset time of CP children within the group

The comparative values of mean voice onset time of CP children within the group showed no significant difference for any of the stop consonants.

Table 3: Showing comparison of mean voice onset time across the groups for the age range of 6.0 - 6.11 years

VOT across the groups (in seconds) -		TD		CP		
S. NO.	Consonant	6.0 - 6.11 yrs		6.0 - 6.11 yrs		p value
		Mean	SD	Mean	SD	
1	Bilabial /b/	0.260	0.054	0.348	0.497	0.08
2	Dental /d̪/	0.361	0.121	0.407	1.022	0.55
3	Retroflex /ɖ/	0.261	0.063	0.428	1.642	0.01
4	Palatal /ʤ/	0.316	0.103	0.434	2.191	0.05
5	Velar /g/	0.291	0.080	0.332	2.782	0.41

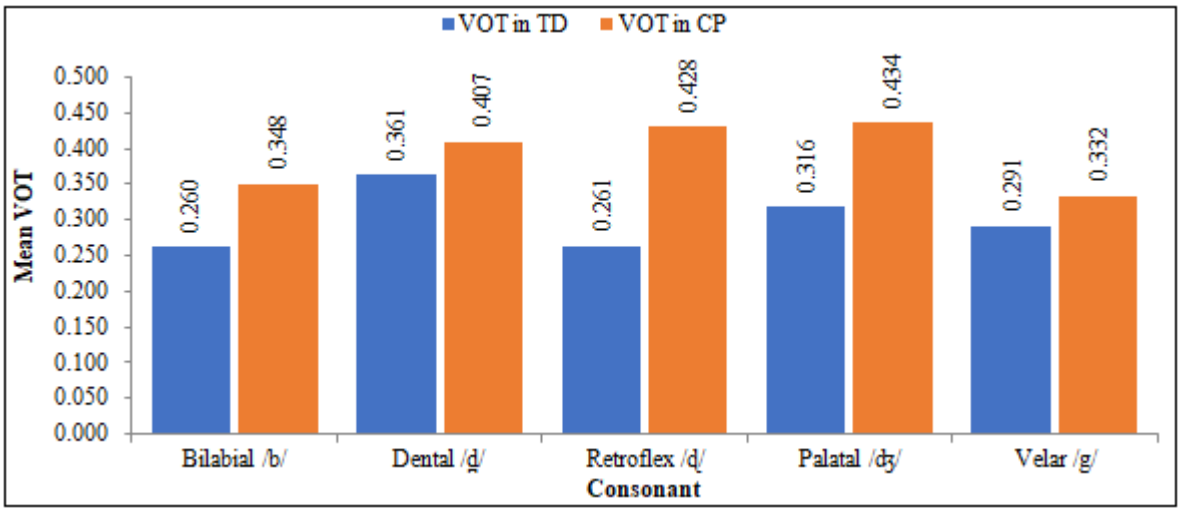

Figure 3: Showing comparison of mean voice onset time across the groups for the age range of 6.0 - 6.11 years

The comparative values of mean voice onset time across the groups for the age range of 6.0 - 6.11 years showed highly significant difference for bilabial /b/, retroflex /ɖ/ and palatal /ʤ/ stop consonants in Hindi.

Table 4: Showing comparison of mean voice onset time across the groups for the age range of 7.0 - 7.11 years

VOT across the groups (in seconds) -		TD		CP		
S. NO.	Consonant	7.0 - 7.11 yrs		7.0 - 7.11 yrs		p value
		Mean	SD	Mean	SD	
1	Bilabial /b/	0.255	0.018	0.382	0.086	0.01
2	Dental /d̪/	0.229	0.033	0.438	0.051	0.00
3	Retroflex /ɖ/	0.259	0.020	0.441	0.051	0.00
4	Palatal /ʤ/	0.284	0.023	0.466	0.035	0.00
5	Velar /g/	0.243	0.027	0.363	0.062	0.00

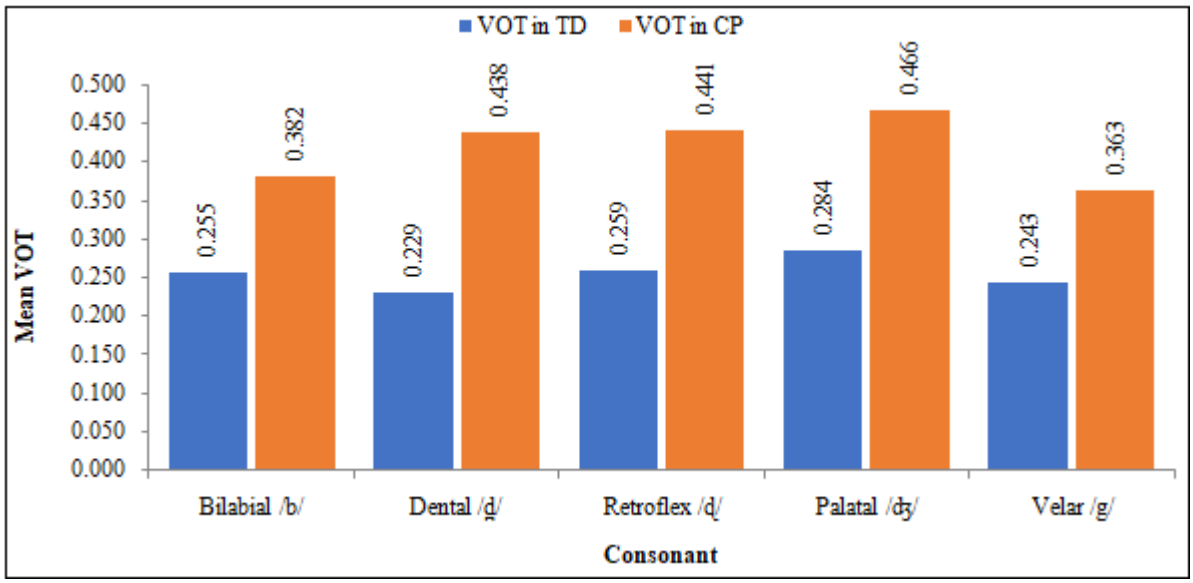

Figure 4: Showing comparison of mean voice onset time across the groups for the age range of 7.0 - 7.11 years

The comparative values of mean voice onset time across the groups for the age range of 7.0 - 7.11 years showed highly significant difference for bilabial /b/, dental /d̪/, retroflex /ɖ/, palatal /ʤ/ and velar /g/ stop consonants in Hindi.

5. Discussion

The present study is a useful reference for comprehending an important temporal aspect of stop consonants, voice onset time, in typical children and children with cerebral palsy speaking Hindi in the age range of 6 to 8 years. The comparative values of mean VOT across the groups for the age range of 6.0 - 6.11 years showed highly significant difference for bilabial /b/, retroflex /ɖ/ and palatal /ʤ/ stop consonants. Whereas, the comparative values of mean voice onset time across the groups for the age range of 7.0 - 7.11 years showed highly significant difference for bilabial /b/, dental /d̪/, retroflex /ɖ/, palatal /ʤ/ and velar /g/ stop consonants in Hindi. It can be clearly concluded from the results that children with spastic CP have significantly longer VOT as compared to typical children speaking Hindi.

Considering the results of study undertaken by Liu, Tseng & Tsao (2000), the findings of the present study can be helpful in predicting speech intelligibility in children with cerebral palsy speaking Hindi. This research work also aligns with the results of Kim & Kim (2019) who compared the acoustic features of Korean stop sounds between adults in dysarthric and typical developing group.

6. Summary & Conclusion

The study at hand offers valuable information on the temporal characteristic, i. e., voice onset time in stop consonants for children between the ages of 6 and 8 years old who speak Hindi, both those developing typically and those with spastic cerebral palsy. Furthermore, this study seeks to contrast the mean VOTs within the groups and across the groups for typical children and children with spastic CP speaking Hindi in the age range of 6 - 8 years. For this purpose, total five non - nasal, voiced and unaspirated stop consonants of Hindi language were used a stimulus - bilabial (/b/), dental (/d̪/), retroflex (/ɖ/), palatal (/ʤ/) and velar (/g/). The voice recordings for all the participants were done and VOTs were tabulated using PRAAT software followed by descriptive statistical analysis to get the comparative values of mean VOT within and across the target groups. The across groups comparative values for the age range of 6.0 - 6.11 years showed highly significant difference for bilabial /b/, retroflex /ɖ/ and palatal /ʤ/ stop consonants. Whereas, the comparative values of mean voice onset time across the groups for the age range of 7.0 - 7.11 years showed highly significant difference for bilabial /b/, dental /d̪/, retroflex /ɖ/, palatal /ʤ/ and velar /g/ stop consonants in Hindi. The results indicated statistically significant prolonged VOT in children with spastic CP as compared to that of typical children speaking Hindi.

7. Clinical Implications

The results of the present study can be effectively applied in clinical settings by the SLPs to understand the temporal characteristics of stop consonants in children with spastic cerebral palsy and their correlation with speech intelligibility. This understanding and correlation is important for the implementation of an effective intervention program.

8. Limitations

This research work has a few limitations like limited sample size and age groups.

9. Future Recommendations

Expanding participant population sizes and age groups - alongside investigating alternative Indian languages - will further enhance the scope and depth of the current research.

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