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ESTUDIOS

Acoustic features of labial and dental plosives in children with hypernasality

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Abstract: Cleft lip and palate (CLP) is a birth defect that can have negative effects on feeding, physical appearance, speech, hearing, and psychological development. Hypernasality resulting from velopharyngeal insufficiency causes high-pressure sounds, including plosives, fricatives, and affricates to be produced in an impaired pattern. In this study, the influence of hypernasality on plosive sounds was investigated. Six children with CLP who had hypernasality and six children with typical development participated in this descriptive comparative study. All the participants were between 10 and 12 years old and were native Turkish speakers. The two groups were matched by age and gender. For the acoustic analysis, stop duration, burst duration, and total duration of each target sound were calculated. In addition, the voice onset time (VOT) was assessed and compared between the groups. A linear mixed-effects model was used for the statistical analysis. This study demonstrates that the children with hypernasality had longer target sound duration and prolonged burst duration of target sounds. Moreover, the results indicate that hypernasality is linked to prolonged closure duration. The study findings show that velopharyngeal insufficiency has an effect on the duration of obstruent sounds. This explains the differences between the hypernasality and typical developed groups. This research suggests that careful evaluation of CLP patients could have a positive impact on CLP speech therapy. Using acoustic measurements, this investigation obtained theoretical results that could potentially point clinicians in the right direction.

Key Words: Cleft lip palate; Hypernasality; Plosive sound; VOT.

ES Características acústicas de las oclusivas labiales y dentales en niños con hipernasalidad

Resumen: El labio leporino con paladar hendido (LPH en adelante) es un defecto de nacimiento que puede tener efectos negativos en la alimentación, la apariencia física, el habla, la audición y el desarrollo psicológico. La hipernasalidad resultante de la insuficiencia velofaríngea provoca que los sonidos de alta presión intraoral, incluidos los oclusivos, fricativos y africados, se produzcan de manera alterada. En este estudio se investigó la influencia de la hipernasalidad en los sonidos oclusivos labiales y dentales. En este estudio descriptivo comparativo participaron seis niños con LPH que presentaban hipernasalidad y seis niños de desarrollo típico. Todos los participantes, emparejados por edad y género, tenían entre 10 y 12 años y eran hablantes nativos de turco. Para el análisis acústico, se calculó la duración de la oclusión, la duración de la explosión y la duración total de cada sonido objetivo. Además, se evaluó y comparó el tiempo de inicio de la voz (VOT, por sus siglas en inglés) entre los grupos. Se utilizó un modelo lineal de efectos mixtos para el análisis estadístico. Este estudio demuestra que los niños con hipernasalidad presentan una mayor duración tanto de la totalidad del sonido objetivo como de la explosión. Además, los resultados indican que la hipernasalidad está asociada a una prolongación de la duración de la oclusión. Los hallazgos del estudio muestran que la insuficiencia velofaríngea afecta a la duración de los sonidos oclusivos. Esto explica las diferencias entre los grupos con hipernasalidad y desarrollo típico. Esta investigación sugiere que una evaluación cuidadosa de los pacientes con LPH podría tener un impacto positivo en la terapia del habla para LPH. Utilizando mediciones acústicas, esta investigación obtuvo resultados teóricos que podrían orientar a los clínicos en la dirección correcta.

Palabras Clave: Hipernasalidad; Labio leporino; Paladar hendido; Sonido oclusivo; VOT.

Sumario: Introducción. Method. Participants. Data Collection Tools. Speech Stimuli and Procedure. Results. Total duration. Burst Duration. Closure duration. VOT Types. Discussion. Conclusion. References.

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Introduction

Resonance and articulation are negatively affected by organic issues induced by cleft lip with cleft palate (CLP). Velopharyngeal insufficiency (VPI) inhibits the production of high pressure in the oral cavity, which is required for the production of obstruent speech sounds (Gibbon, Lee & Yuen, 2010; Kuehn & Moller, 2000). The obstruent sounds in the Turkish can be categorized as plosive [p, b, t, d, k, g], fricative [f, v, s, z], and affricate [t͡ʃ, d͡ʒ] sounds, which are the most susceptible to hypernasality in children with CLP.

It is essential to recognize that individuals with CLP may have both compensatory and obligatory speech disorders. In contrast to obligatory speech errors, which are the result of structural or neu-rogenic problems, compensatory errors are the result of early mislearning and behaviors learned to compensate for physical problems. In obligatory speech errors, oral sounds are transformed into nasal sounds as a result of nasal leaks induced by VPI. By contrast, learned speech errors occur in individu-als with CLP when their articulation is altered to eradicate or reduce nasality. Speech therapy can cor-rect learned speech errors but has little effect on obligatory speech errors (Kotlarek & Krueger, 2023).

The optimal course of action for patients with CLP would first be to correct any structural issues with surgical procedures and then treat any possible articulation faults. However, for various reasons, these surgical procedures may not be performed. Therapies may reduce learned speech errors in these in-dividuals, but obligatory speech errors caused by hypernasality will inevitably persist. Numerous stud-ies (Alwan, Jiang & Chen, 2011; Marino, Dutka, Manicardi, Gifalli, Silva & Pegoraro-Krook, 2020; Oren, Kummer & Boyce, 2020; Saxon, Liss & Berisha, 2019) have been conducted on the influence of hyper-nasality on the perception of plosive sounds.

To form an acoustic signal, the articulators must operate synchronously. For each oral speech sound, the velopharyngeal mechanism drives the velum up while it descends to produce nasal speech sounds. This mechanism does not function independently, as other articulators undoubtedly alter the velopharyngeal movement. The velopharyngeal mechanism plays a crucial role in the formation of oral and nasal speech sounds and displays significant anatomical and physiological abnormalities in cases of CLP. Misarticulations are closely associated with the type and severity of the cleft, organic abnor-malities, the presence or absence of VP, dental fistula, and occlusion defects (Kuehn & Moller, 2000; Lohmander & Olsson, 2004).

Children with CLP are unable to produce speech sounds that require separation of the oral and na-sal cavities, making it difficult for them to differentiate the traits of obstruent speech sounds such as the plosive, fricative, and affricate consonants.

Voice onset time (VOT) is one of the most important characteristic parameters for assessing plosive sounds. VOT is the interval between the release of a plosive consonant and the beginning of voicing, that is, the vocal folds vibrating (Kent, 2002). It is a reliable acoustic marker for distinguishing between voiced and voiceless plosive sounds: the voiced plosive sounds [b, d, g] have shorter VOTs than the voiceless plosive sounds [p, t, k] (Kent, 2002; Lisker & Abramson, 1964).

When plosive sounds are in the first syllable of a word, the height of the next vowel affects the VOT. This is a voicing property in which the location of the stop sound influences the VOT (Klatt, 1980). The VOTs of plosive sounds that precede a high vowel are longer than those preceding a low vowel.

In a study conducted by Sankar (2014), it was shown that children with cleft lip and palate (CLP) had longer voice onset time (VOT) values before their surgery compared to a control group. Furthermore, after the surgery, the VOT values were found to be longer compared to the pre-operative condition.

VOT are affected by physiological characteristics such as age and lung capacity (Eguchi & Hirsh, 1969), speech rate and phonetic content (Allen, Miller & DeSteno, 2003). VOT values can also be af-fected when speech mechanism is compromised by medical conditions such as Parkinson’s disease, hearing loss, depression, and respiratory diseases (Forrest, Weismer & Turner, 1989).

According to the location of their articulation, the Turkish plosive consonants can be divided into three groups: bilabials [p, b], dentals [t, d], and velars [k, g]. According to the voicing feature, the groups are fur-ther divided into two categories: voiced and voiceless. Unlike English, the [t] and [d] consonants in Turkish are typically dental and less frequently alveolar. Turkish velar plosives consonants have two allophones: velar and palatal (Eker, 2007): the /k/ and /g/ consonants are velar [k, g] in the context of back vowels and palatal [c, ɟ] in the context of front vowels. In addition to this, the three voiceless plosives are aspirated in stressed syllables.

VOT can be divided into 3 types. i) zero VOT, ii) positive VOT and iii) negative VOT. Lisker and Abramson (1964) describe these three VOT types as follows:

i) Zero VOT: As seen in Figure 1, vocal fold vibration and the release of plosive sound occur virtually simultaneously. In other words, plosive sounds occur as soon as vibration begins. Zero VOT is also known as a short voicing lag, ranging from 0 to +25 ms.

ii) Positive VOT: Positive VOT describes the moment from the start of voicing to the release of the plosive. Often known as a voicing lag, it ranges from +60 to +100 ms.

iii) Negative VOT: In negative VOT, as depicted in Figure 1, voicing begins before the release of the plosive. In languages such as Russian, Spanish, Dutch, and Hungarian, it is referred to as the leading voice. However, phonetically, not all voiced sounds possess this phonological property. For example, in languages such as English and German, the voiced plosive [d] may not have a voicing lead (Kang & Nagy, 2016). Negative VOT ranges from –125 to –75 ms, longer than other VOT types.

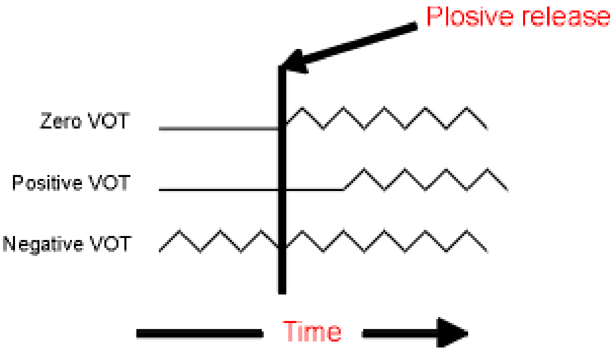

Figure 1. VOT types

Source: http://www.phon.ucl.ac.uk/home/johnm/siphtra/plostut2/plostut2-2.htm

VOT and voicing contrast cannot be explained simply by the adduction and abduction of the vocal folds. Motor equivalency is the synchronization between the movements of the articulators that allows the vocal folds to continue vibrating or working to produce voiced sounds (Cho, Whalen & Docherty, 2019; Ünal-Logacev, Fuchs & Lancia, 2018). This is known as cavity extension and is performed to produce a pressure difference between the subglottal and supraglottal regions. In the Turkish language, as the voiced duration increases, the palate contact diminishes in plosive sounds, and the intraoral pressure velocity of the voiced obstruent sounds increases more slowly than that in voiceless obstruent sounds. Moreover, voiced plosive sounds have a lower maximum intraoral pressure (Ünal-Logacev et al., 2018). While cavity volume measurement is essential for voiced plosive sounds, it is of little value for voiceless plosive sounds (Westbury, 1983).

In the Turkish language, a two-way voicing contrast exists between voiced and voiceless plosive sounds (Kopkallı-Yavuz, 2000): the voiced plosive sounds are [b, d, g], and the voiceless plosive sounds are [p, t, k]. The VOT differs between voiced and voiceless sounds. The VOTs for the voiceless plosive sounds [p, t, k] are +45, +50, and +69 ms, respectively. The VOTs for the voiced plosive sounds [b, d, g] are –66, –53, and –10 ms, respectively (Öğüt, Kilic, Engin & Midilli, 2006). Thus, it is evident that voiceless and voiced plosive sounds have positive and negative VOTs, respectively. However, in languages such as German and English, phonologically voiced plosive sounds can have a positive VOT.

To date, all voicing contrast studies have focused on adults and reported that intraoral pressure is influenced by some conditions, such as velopharyngeal dysfunction. Thus, the aim of this study was to evaluate how voicing contrast is altered. In this regard, the following research question was answered: Are there differences in burst, closure duration, and total duration between voiced and voiceless plosive sounds in typically developing children and children with hypernasality?

Method

This is a descriptive comparative study. The reporting of unpublished data in this paper was approved by the Ethics Committee of Anadolu University under protocol No. 7422. All procedures were conducted in accordance with the institution's ethics guidelines and the Helsinki Declaration of 1964. As all participants were young children, written consent was obtained from their parents or guardians.

Participants

The participants (n = 12) in this research were secondary school students aged 10 to 12 ($\bar{x}$ = 11 years old) who resided in Eskisehir. All the participants were native Turkish speakers. The participants were divided into two groups: the group with hypernasality (GWH), that included three boys and three girls (a total of six participants) with a medical history of hypernasality and at least one previous palate operation, and the typically developed group (TDG), that also included three boys and three girls (a total of six participants). The participants in the two groups were matched for age and gender characteristics. Inclusion criteria for the GWH were children with hypernasality without fistula, any resonance disorders other than hypernasality, velocardiofacial syndrome and speech language disorders. The inclusion criteria for the TDG were children without any organic problems or speech and language disorders.

Data Collection Tools

The *Cleft Lip and Palate Assessment Form* (Ünal-Logacev, Kazanoğlu, Balo & Nemutlu, 2018) was used to evaluate the medical history, oral-peripheral function, and speech/resonance characteristics of the participants with CLP. In addition, the Turkish articulation test *SST* –Türkçe Sesletim-Sesbilgisi Testi– (Topbaş, 2006) was administered to exclude participants with compensatory articulation issues. The participants' nasality was evaluated using a nasometer (Pentax Medical, Nasometer II: 6450).

Speech Stimuli and Procedure

In this study, [p, b, t, d] speech sounds were positioned as word initially. Each word was contained in a carrier phrase. To control the phonetic environment of the target sounds, the preceding and following sounds were set to [ʌ]. The sentence [ɛdʌ tʌbʌk dɛdı] (*Eda said plate*) shows how the targeted sound /t/ was initially inserted into a word, followed by its placement in a carrier phrase and encirclement with [ʌ] vowel.

Four plosive sounds were targeted in this study. Each sound was inserted into five distinct words, resulting in 20 tokens. These tokens were randomly shuffled five times to produce five distinct lists. All participants read the lists at random, and 2700 tokens were evaluated. The distribution of the number of tokens was homogeneous. Any data found to be corrupted during the collection process were excluded from acoustic analysis.

The participants were instructed to read sentences at a typical speech rate. They were required to reread the sentence every time they made a reading error. The recordings were performed in a sound-isolated room at the Anadolu University Speech and Language Disorders, Education, Research, and Application Center using a KayPentax Computerized Speech Lab (CSL) Model 4500 and Sennheiser ME64 (dynamic and cardioid) microphone. The records were sampled at a frequency of 22,000 Hz.

Data Analysis

The open-source software *Praat* Version 6.0.14 (Boersma, 2001) was used for the acoustic analysis. The stop, burst, and total durations of [p, b, t, d] were calculated. In addition, VOT type and duration were measured. Figure 2 illustrates the annotation of a target sound [t]. The onset of the targeted sound was defined as the first and second formant offsets of the preceding vowel (first dashed line). As the target offset, the onset of the first two formants of the following vowel was determined. Finally, open-source statistics software *R* was used in the statistical analysis.

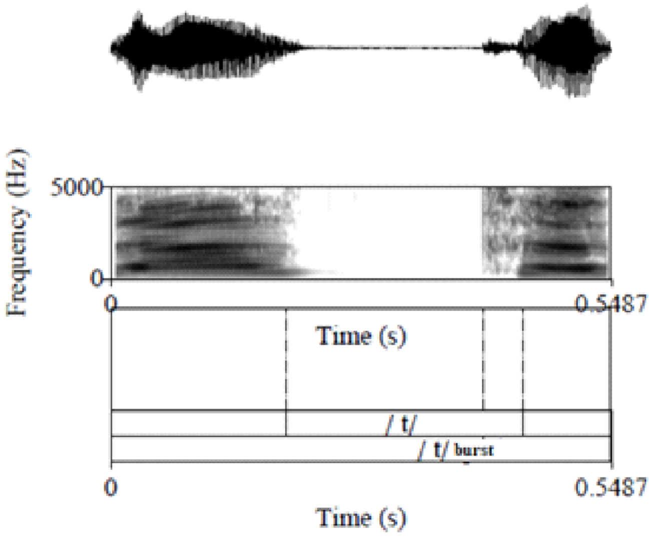

Figure 2. A sample drawing provided by Praat Picture which shows sound's onset and offset

Results

In this study, the parameters investigated were total duration, burst duration and closure duration of the plosive sounds.

Total duration

The influence of hypernasality, place of articulation, gender, and voicing on the total duration of the target sounds are depicted in Figure 3. The presence of hypernasality made the total duration of the voiceless [p] and [t] significantly longer than those in the TDG. The time gap between the voiced and voiceless sounds was shorter in the TDG than in the GWH. From the perspective of place of articulation, it is evident that the total duration of [p] was longer than that of [t] in the GWH. Although the gender variable in the GWH caused the total duration of the voiceless target sounds to be substantially longer than those in the TDG, the total duration of the voiced sounds in both groups were nearly identical.

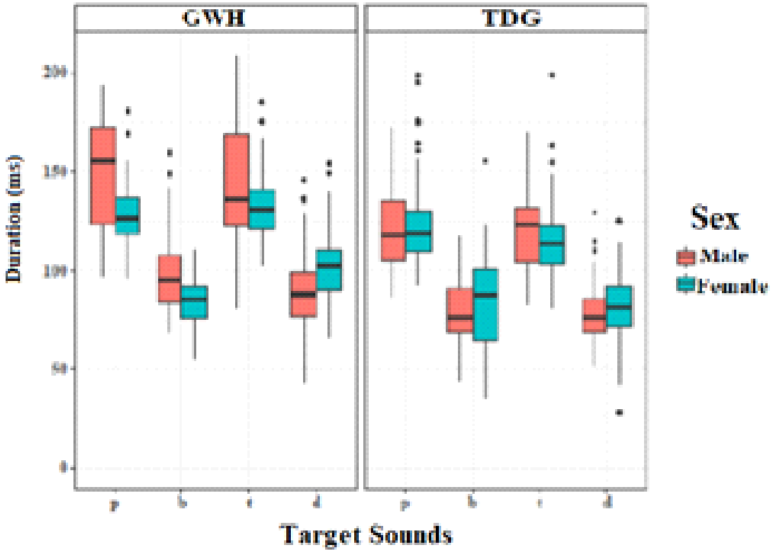

Figure 3. Target sound durations in milliseconds

To determine the effect of hypernasality on total duration, a linear mixed-effect model was applied to the place of articulation, gender, and voicing of the target sounds. Table 1 demonstrates that the effect of hypernasality on total duration was statistically significant (β = 15.84, SE = 7.19, *t* = 2.20, p = .028). The total durations of the voiced sounds [b] and [p] were statistically significantly shorter (β = –41.91, SE = 3.84, *t* = –10.93, p < .001 and β = –41.28, SE = 3.56, *t* = –11.59, p < .001). The TDG generates these sounds over an extended period. Hypernasality had no statistically significant impact on the gender variable. The descriptive statistics for the target sound total durations are presented in Table 2.

Table 1. Effects of hypernasality, target sounds' place of articulation, gender, and voicing on duration

	β	**SE**	**t**	**p**
(Intercept)	86.94	3.70	23.51	< .001
Hypernasality$_{\text{GWH-TDG}}$	15.84	7.19	2.20	.028
MALE-FEMALE	-0.09	7.19	-0.01	.992
Target Sound/b/-/p/	-41.91	3.84	-10.93	< .001
Target Sound /t/-/p/	-0.81	2.56	-0.32	.749
Target Sound /d/-/p/	-41.28	3.56	-11.59	< .001
Hypernasality$_{\text{GWH-TDG}}$: Male-Female	2.93	14.39	0.20	.841

Table 2. Descriptive data of phonation duration in milliseconds

	GWH				TDG			
	Max.	Min.	Mean	SD	Max.	Min.	Mean	SD
/p/	441.68	95.50	141.34	3.02	381.78	86.80	125.57	2.75
/b/	273.20	55.22	96.48	2.65	256.15	35.17	84.52	2.23
/t/	600.91	81.29	146.19	4.36	339.93	81.79	122.53	2.79
/d/	372.15	43.14	99.06	2.67	285.15	28.22	81.88	2.15

Burst Duration

Another parameter investigated in this study was the burst durations of the [p, b, t, d] plosive sounds (Figure 4).

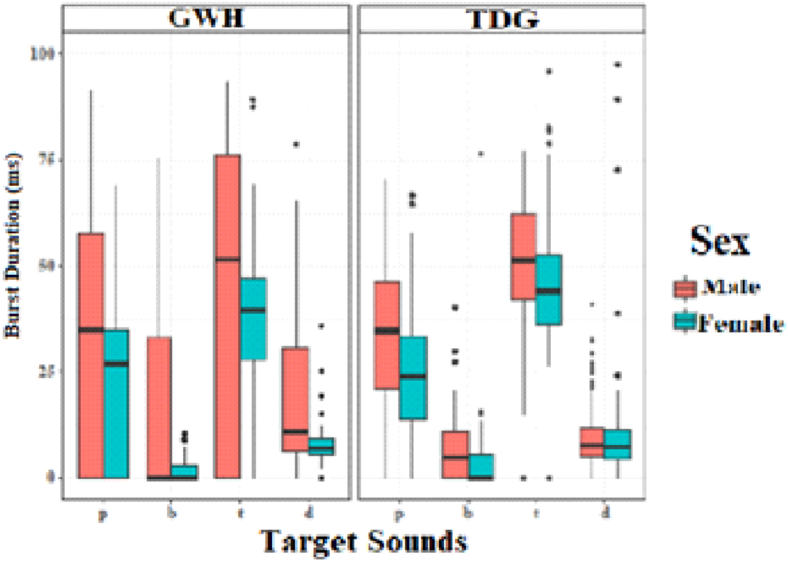

Figure 4. Burst Duration of speech sounds in milliseconds

Table 3 shows the effects of hypernasality, place of articulation, gender, and voicing on the burst durations of the target sounds in both groups. The burst durations of the voiceless sounds significantly differed according to the presence of hypernasality. The [t] sound had the longest burst duration within the context of place of articulation. In the GWH, compared with the female participants, the male participants produced the target sounds with significantly longer burst durations. In addition, all participants in the GWH had much longer burst durations of the voiceless sounds than their counterparts. In the TDG, the burst durations of the voiceless sounds were longer than those of the voiced sounds. Burst duration values are presented in Table 4.

Table 3. Effect of hypernasality, target sounds' place of articulation, gender and voicing on burst duration

	β	**SE**	**t**	**p**
(Intercept)	17.92	2.94	6.10	< .001
Hypernasality$_{GWH\text{-}TDG}$	1.73	5.57	0.31	.757
Male-Female	7.38	5.57	1.32	.187
Target Sound/b/-/p/	-20.44	2.67	-7.67	< .001
Target Sound /t/-/p/	17.58	2.08	8.47	< .001
Target Sound /d/-/p/	-16.03	3.09	-5.18	< .001
Hypernasality$_{GWH\text{-}TDG}$: Male-Female	10.71	11.15	0.96	.337

Table 4. Descriptive data of burst duration in milliseconds

	GWH				TDG			
	Max.	Min.	Mean	SD	Max.	Min.	Mean	SD
/p/	169.03	0.48	33.33	2.87	70.46	0.00	28.49	1.53
/b/	199.80	0.00	14.68	2.73	76.47	0.00	5.55	0.73
/t/	261.69	0.00	46.41	3.27	112.10	0.00	48.75	1.70
/d/	218.73	0.00	15.85	1.98	97.48	0.00	10.41	1.06

We found that the influence of hypernasality on burst duration did not statistically significantly differ between the groups. Nonetheless, the voicing features of the sounds showed important differences. The burst durations of the voiced sounds were shorter; [b] sound: β = –20.44, SE = 2.67, *t* = –7.67; [d] sound: β = –16.03, SE= 3.09, *t* = –5.18). The burst duration of the [t] sound was longer than that of the /p/ sound (β = 17.58, SE = 2.08, *t* = 8.47). Among the target sounds, [t] had the longest burst duration. Gender was not a statistically significant contributor to burst duration.

Closure duration

The third parameter described in this study is the closure durations of the [p, b, t, d] plosive sounds.

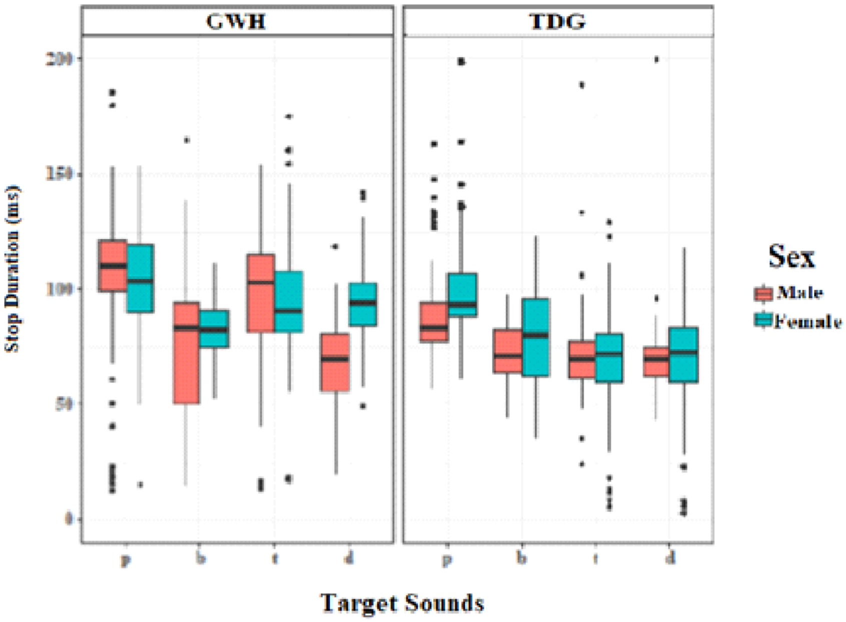

Figure 5. Closure durations for speech sounds in milliseconds

According to the values given in Figure 5, the effects of hypernasality, place of articulation, gender, and voicing on the closure durations of the target sounds are portrayed in both groups. The participants in the GWH have had longer closure durations than those in the TDG. In both groups, the [p] sound had the longest closure duration. The descriptive statistics for the closure duration values are presented in Table 6.

Table 5. Effect of hypernasality, target sounds' place of articulation, gender and voicing on closure duration

	β	SE	t	p
(Intercept)	67.95	2.80	24.30	< .001
Hypernasality$_{\text{GWH-TDG}}$	12.91	5.31	2.43	.015
Male-Female	-9.03	5.31	-1.70	.089
Target Sound/b/-/p/	-22.41	4.46	-5.02	< .001
Target Sound /t/-/p/	-17.13	3.02	-5.67	< .001
Target Sound /d/-/p/	-24.98	4.63	-5.39	< .001
Hypernasality$_{\text{GWH-TDG}}$: Male-Female	-15.07	10.61	-1.42	.156

Table 6. Descriptive data of closure duration in milliseconds

	GWH				TDG			
	Max.	Min.	Mean	SD	Max.	Min.	Mean	SD
/p/	439.92	12.38	108.01	3.51	346.71	57.26	97.07	2.75
/b/	267.75	15.12	81.79	2.58	256.15	35.17	78.96	2.14
/t/	339.22	13.56	99.78	3.28	294.66	5.30	73.78	2.85
/d/	368.27	20.58	83.20	2.75	258.06	2.83	71.47	2.09

As described in Table 5, the hypernasality variable had a statistically significant effect on closure duration (β = 12.91, SE = 5.31, t = 2.43, p = .015). The examination of the closure durations of the target sounds revealed that the [b, t, d] sounds had shorter closure durations than the [p] sound ([b] sound: β = –22.41, SE = 4.46, t = –5.02, p < .001; [t] sound: β = –17.13, SE = 3.02, t = –5.67, p < .001; and [d] sound: β = –24.98, SE = 4.63, t = –5.39, p < .001).

VOT Types

The relevant information regarding the VOT types is given in Table 7. As shown in Figure 6a and Figure 6b the participants in the GWH unexpectedly produced [p] and [t] sounds with negative VOTs. None of the participants in the TDG had a negative VOT in producing the /p/ sound, but three participants had a negative VOT in producing the [t] sound. The number of zero VOTs was higher in the GWH than in the TDG.

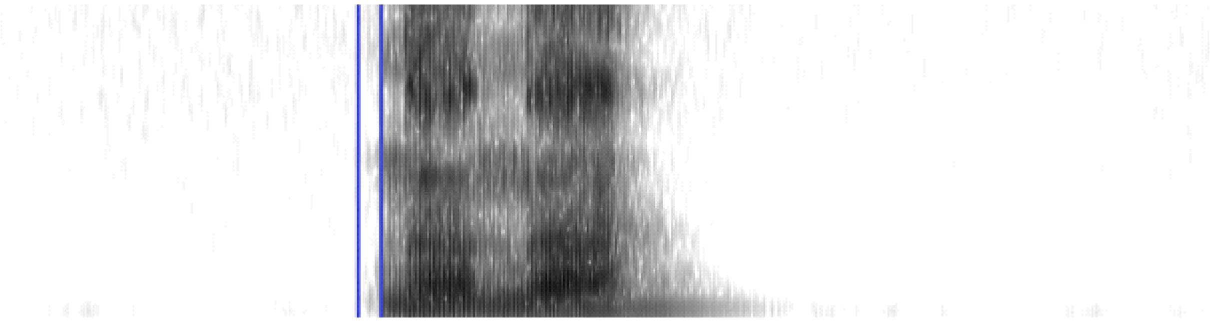

Figure 6a. Wideband spectrogram of the word [pʌdʌ] in a hypernasal subject (negative VOT value).

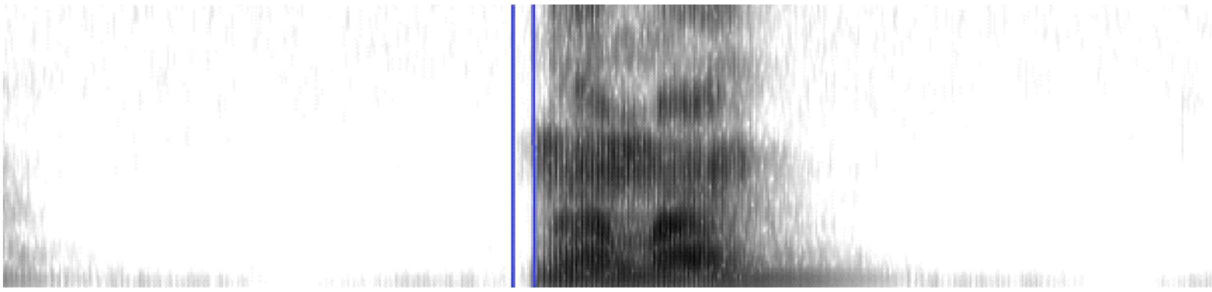

Figure 6b. Wideband spectrogram of the word [tʌbʌk] in a hypernasal subject (negative VOT value).

Table 7. Total numbers of plosive sounds' VOT types

	GWH					TDG				
	/p/	**/b/**	**/t/**	**/d/**	**Total**	**/p/**	**/b/**	**/t/**	**/d/**	**Total**
Zero	49	83	31	13	176	27	61	9	9	106
(%)	27.8	47.1	17.6	7.38		25.4	57.5	8.4	8.4	
Neg. VOT	12	48	33	113	206	-	57	3	108	168
(%)	5.8	23.3	16	54.8			33.9	1.7	64.2	
Pos. VOT	88	14	81	20	203	119	29	137	32	317
(%)	43.3	6.8	39.9	9.8		37.5	9.1	43.2	10	

Discussion

In this study, target sounds appeared to be affected by hypernasality. Therefore, the total durations of the target sounds (specifically voiceless sounds) were longer in the GWH than in the TDG. Thus, we can infer that the participants included in the GWH exhibited a tendency to generate prolonged plosive sounds as a tactic to effectively accumulate intraoral pressure. This finding is consistent with those reported in other studies (Gaylord, 2006; Shin et al., 1998). The total durations of the target sounds are affected by their backness and voiceless feature. This finding is also consistent with that of another study (Sankar, 2014). This study clearly demonstrates that gender had no significant effect on target sound total duration. Öğüt et al. (2006) found a similar finding in their study.

The effect of hypernasality on the burst durations of target sounds is not statistically significant. Further study with more participants is needed to confirm these results. The burst durations of the target sounds were longer in the GWH than in the TDG, a finding supported by a previous study (Warren & Mackler, 1968). The reason for this is that the participants in the GWH took longer to provide their listeners with a clearer acoustic clue. The burst duration was longer in the voiceless plosive sounds than in the voiced plosive sounds. The interval between the vocal fold vibration and onset of articulation resulted from the vocal tract volume difference. In other words, it is smaller, a fact pointed out in another study (Weismer, 1980).

While the burst durations of plosive target sounds are shorter, they become longer as the place of articulation of the target sounds is substituted by a back consonant. This finding is supported by other studies (Forner, 1983; Shin et al., 1998).

The closure durations of the target sounds are influenced by hypernasality. In this case, the closure durations were longer in the GWH than in the TDG. This finding supports other acoustic studies (Forner, 1983; Shin et al., 1998). This is derived from the fact that the participants in the GWH could not create the required intraoral pressure for stop sounds and articulate stop sounds with a prolonged VOT to compensate for their VP dysfunction. In addition, the closure durations were longer in the voiceless stop sounds than in the voiced sounds. This finding contributes to the existing research (Warren & Mackler, 1968). In terms of closure duration, gender is not a significant variable.

Another significant finding of this study is the identification of an unexpected quantity of negative VOT in the GWH. This implies that the GWH transformed the voiceless stop sounds into their voiced counterparts. Another study conducted by Forner (1983) reported a similar result. This could be explained by the fact that the participants in the GWH compensated for the weakened voiceless stop sounds resulting from hypernasality by overemphasizing them. It could be closely connected to the relationship between sublaryngeal and supralaryngeal pressure coordination, which is essential to maintain voicing. For this to happen, the sublaryngeal pressure must be higher than the supralaryngeal pressure. When the pressure is equal between these two areas, the sound becomes voiceless. Provided that hypernasality is present, the pressure might not be evened up because of air leakage, and voiceless sounds might end up being voiced.

Conclusion

In this study, the effects of hypernasality, place of articulation, gender, and voicing on the total duration, burst duration, closure duration, and VOT type of the target sound and their relationships with hypernasality were investigated. As a result, we can infer that hypernasality impacts the total duration and closure duration of target sounds. In the GWH, the total duration and closure duration of the target sounds were longer than those in the TDG. Moreover, hypernasality showed no statistically significant effect on the burst durations of the target sounds.

According to our findings, hypernasality influences the total duration and closure duration of the voiceless stop sounds. Regardless of the voicing features of the target sounds, the participants in the GWH produced longer target sounds. In terms of VOT type and relationship with hypernasality, the GWH had more negative VOT than the TDG. Owing to hypernasality, some of the voiceless target sounds turned into voiced ones as it was shown in the results sections.

In conclusion, the data obtained from this study could have a positive impact on CLP speech therapies. Given the findings of this study, it is evident that GWH has developed techniques, such as the elongation of plosive sounds, to generate adequate intraoral pressure. Consequently, clinicians may need to adjust their therapy plans accordingly when addressing speech sound disorders in patients with CLP who have hypernasality. Furthermore, it is imperative for clinicians to keep in mind that hypernasality causes a substantial influence on the high-pressure sounds that they aim to address in their therapeutic interventions. That is why they need to adjust their therapy plans by considering effects of hypernasality on specific sounds. The acoustic measurements investigated in this study and the consequent objective results could provide both researchers and clinicians with theoretical knowledge that could broaden their points of view. The administration and evaluation of therapies can be performed simultaneously. Learning how to use acoustic analysis in clinical practice could point clinicians to the right direction. The findings of this study can shed some light on future studies.

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Author Contributions

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