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# Description of Three Time-Domain Speech Features in Children with Down Syndrome: A Pilot Study

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ABSTRACT

**Background:** The present pilot study aims at investigating the three features of time domain in speech in Persian-speaking children with Down syndrome.
**Methods:** In this Cross sectional study, our sample consisted of two 3-8-year-old children (2 males) with Down syndrome (4.9 years old and standard deviation of 1.52). Inclusion criteria were children with Down syndrome, aged 3-8 years old, no neurological or motor disorders, sensory disorders and psychiatric disorders. The voice sample of the children was analyzed with Praat, and the phonetic features of the voice onset time, vowel duration time and closure duration time were evaluated and descriptive statistics were reported by the Statistical Package for Social Sciences version (SPSS, Inc., Chicago IL, USA; version 16).
**Results:** we found that in /pa/, the mean of the voice onset time variable is (0.04±0.00) and in /ta/ the mean of the voice onset time variable is (0.04±0.00).
**Conclusion:** According to the results of this study, it can be concluded that the speech time domain features in Persian-speaking children with Down syndrome were similar to these features in other languages, which could be due to problems with the tone and muscular strength in these children.



## Introduction

Down syndrome is the most common genetic disorder along with mental retardation, with the prevalence of 1 out of 800 to 1000 births. A variety of disorders are observed in this syndrome, including mental disabilities, facial-skull disorders, hypotonia, oral-motor disorders such as tongue protrusion, non-normal closure of lips, inappropriate jaw functions, small oral cavity, and high-arched and narrow palate [1-4]. These structural, anatomical and motor differences have an impact on the perceptual evaluation of their voice quality [3, 5, 6].

In a study on the comparison of children with Down syndrome with the children suffering from fragile X syndrome, Barnes et al. concluded that Down Syndrome-related motor pathologies have a profound effect on the coordination and timing of articulation movements, and Down Syndrome children are not able to produce fast substitution movements which are required for generating multi-syllable words [2, 5, 7]. Also, due to hypotonic problems and speech muscle control in subjects with Down syndrome, the muscle relaxation stage is longer in these subjects which results in prolonged duration time and a high variety in the vowel duration time in subjects with Down syndrome [8]. Despite longer laryngeal muscle relaxation stage, the muscle stagnation is increased and the muscles require a higher potential

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for activation, which is related to the longer duration time in the production. However, it seems that the longer duration time is related more to the muscle control than to anatomical anomalies. To confirm, studies found a hindrance in the development of the motor control of speech in children with Down syndrome compared to the same-aged normal children [9]. In previous studies on differently-aged subjects with Down syndrome, the results showed that the time of production of syllables is longer in children than adults, which seems to be due to the development and maturity of the neuromuscular system in the speech production mechanism. In addition, the time and variability of vowel duration decrease with age [10-13]. On the one hand, studies on vowel formant frequencies in people with Down syndrome are very limited in both children and adults, and the results of these studies are somewhat contradictory [14]. To the best of our knowledge, there are no studies on the analysis of the characteristics of the time domain of the vowel duration time, voice onset time and closure duration time of the stop consonants in Persian-speaking subjects with Down syndrome in Iran. On the other hand, studies have shown that language and culture are important factors in diadochokinetic movements and affect the speed of syllable and speech production [15-17].

Therefore, the present paper aims at studying the features of time domain (voice onset time, vowel duration time and closure duration time of the stop consonants[18]) in Persian-speaking children (girls and boys) with Down syndrome in Consonant-Vowel (CV) units using phonological and oral-motor tasks and their descriptions in these children. The results of this study will better inform the therapists of the voice quality of children with Down syndrome, and provide a more accurate motor-oral evaluation and etiology of voice disorders.

## Methods

*Participants*

In this Cross sectional study, ten 3-8-year-old children with Down syndrome (6 girls and 4 boys) were selected from among patients referring to Arman Speech Therapy Center. It is noteworthy that of these 10 children ultimately only two children correctly stated the diado / pa / and / ta / test for the following reasons. We achieved valuable results about the reasons of inability in executing diado tasks in children with Down syndrome which were presented in the discussion section of this pilot study. All the subjects were unilingual Persian speakers. Inclusion criteria were children with Down syndrome; aged 3-8 years old; no neurological, motor (such as cerebral palsy) or psychiatric disorders (such as autism), which were all confirmed by a pediatric neurologist, and sensory disorders (such as hearing loss which was confirmed by a Pure Tone Audiometry (PTA); having the ability to produce single-syllable diado; a good level of comprehension; and collaboration in the test process. Primary evaluation of the subjects for inclusion in the study and documenting their samples were performed by an expert with Msc in speech and language with ten years of working experience in developmental disorders.

To record the voice of the subjects, we used the Solic microphone model SLR-112 with a frequency response of 100 Hz to 16 kHz with a high voice resolution in the reproduction of time and frequency characteristics of the signal as well as a Sony notebook model VGN-SR210J. According to the professional ethics in the research, in order to obtain the informed consent of the parents of the children concerned, the necessary procedures were explained and they were ensured on confidentiality. A diadochokinetic test with CV syllabic structure was performed on all subjects. At the bilabial level the syllable /pa/ and at the tongue tip level the syllable /ta/ were used. Recording was carried out in a clinical room with the noise intensity of 20 dB, a quiet environment without any ambient noise. The children's voice was recorded by the Praat software with the 16-bit resolution and the sampling frequency of 16kHz. The sampling frequency was 44.1 kHz during recording which was reduced to 16 kHz for the calculation of time domain parameters. The audio file format is wav. The test procedure was explained to the subjects before the test. Each participant was asked once to repeat the syllable that the examiner says with the maximum speed. The microphone was placed at a distance of 10 cm from the subject and at a 45° angle [7], and the subject was asked to repeat the syllable /pa/ and then the syllable /ta/ with the maximum speed after the voice recording started. In order to ensure recording of the best sample of the subject's diado, the diado of each syllable was recorded 3 times [4]. The test stimuli were the Persian labiodental voiceless stops so that the calculation of the variables becomes easier. Since phonemes are distinguished by the three characteristics of the place of articulation, manner of articulation and voicing, the voice onset time can be used as an acoustic key in speech comprehension. The voice onset time is the time span between the voice onset of the previous or the next phoneme until the explosive release. The voice onset occurs before, concurrently or after the closure opening. To calculate the voice onset time, using the signal synchronization and speech mapping spectrum, the time interval between the closure opening and the onset of laryngeal pulse was taken into account. For the voice onset time variable, the duration of all voice onset iterations was first obtained in 10 s, and the averages of the three 10s iterations were again averaged [18].

In Figure 1, the determination of the voice onset time for a child with Down syndrome is shown. The criterion for determining the vowel duration time, was considered to be the time span between the start and the end of the second formant by taking into account the spectroscopy visual signals, i.e. the time span between the place where, for the first time, after the explosive aspiration, the second formant in the laryngeal pulse is observed, and the place it disappears. Listening to the voice articulated in the time interval of the vowel duration mapped in the spectrum reveals the CV syllable instead of the vowel itself, which is due to the co-articulation of the consonant and the vowel. Initially, for the vowel duration, all vowel durations were averaged over a period of 10 seconds, and then the averages of all three stages of the execution

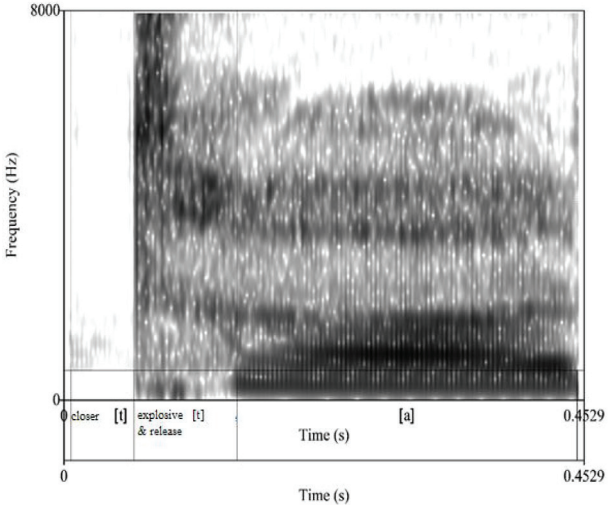


**Figure 1:** Method of determination of the voice onset time in a child with Down syndrome x-axis shows time in seconds. y-axis shows frequency in Hertz.

of stop consonant tasks were again averaged [18]. The operational resolution of the closure duration of the initial voiceless stop consonant is the time interval from the closure onset of the speech device to the explosion line that is the same as the opening moment of the closure. Closure duration was only calculated at the points of the mapping spectrum where the continuous explosion line was completely observable. In cases where the child could not produce diado continuously, the noises in the time domain and frequency domain were very similar to the explosion line, making them difficult to distinguish. At first, for the closure duration, the durations of all iterations of the closure duration were averaged in 10 s and then, the averages of diado iterations of stop consonants were again averaged [18]. Finally, from among the recorded voices of 10 subjects, data from two 3-8-year-old ones (4.9 years and SD 1.52) were analyzed. Data from four subjects were excluded from analysis due to the following: aperiodicity in the spectrum, lack of coordination and stability in production, and physiological factors. Some children, when repeating the diado /ta/ and /pa/, pronounced only a few of them without the proper order, and pronounced the rest as /da/ and / ba/ which are voiced. Some others changed the vowels and consonants and stated the syllables as /ba/, /ma/ or /na/. These two varieties indicate lack of coordination and instability in production. In fact, these children could not control vibrations of their vocal cords constantly. Also, the physiologic factors, including the aspirated production of vowels which are expressed as vowels, and the long pauses between iterations, were excluded from the analysis process. In the aspirated production, the acoustic boundaries, which are, by definition, the duration of the vowel, could not be observed. It should be noted that some of the data of these remaining six subjects have not been recorded for various reasons, including environmental noise (interference and non-recognizable frequencies), very low resolution of the production (there was no definite boundary between two or even more waves, and sometimes the waves were so tangled that the boundary of the end of the vowel durations could not be found with the closure duration), very poor production (as if the child had no lip closure), and in some cases incomplete recording of the sound at the start or end of voice recording (no complete vowel duration). Four out of six subjects could constantly express /ba/ and /da/. In these subjects, there could be seen a voiced prevocalic substitution process over normal growth at the age of 3 to 4 years [19]. Nevertheless, the production of these four subjects is proportional to the level of their speech development. The two remaining subjects expressed the syllables /pa/ and /ta/ correctly and data from these two subjects were analyzed.

*Statistical Methods*

In this study, recorded sound samples, three acoustic parameters of the voice onset time, vowel duration time and closure duration time were extracted over the entire spectrum from the 10s sound records, and the data were statistically analyzed by the SPSS v.16. The findings of the descriptive statistics of each group are presented separately.

## Results

Ten children with Down syndrome (6 girls and 4 boys) aged 3 to 8 (4.9 years old and standard deviation 1.52) were selected from among patients referring to Arman Speech Therapy Center of Isfahan. Four subjects were excluded from the analysis for the reasons mentioned in the Methodology Section. Finally, from among the recorded voices of 10 subjects, data from two were analyzed. Tables 1 and 2 show the mean and standard deviation of each acoustic parameter (voice onset time, closure duration of the stop consonant, and vowel duration) for both syllables of /pa/ and /ta/ in the Down syndrome children with the correct pronunciation.

**Table 1:** Descriptive data of mean and standard deviations for the syllable /pa/

| Acoustic Parameters /pa/ | Mean±SD |
|---|---|
| Voice onset time | 0.04±0.00 |
| Closure duration of stop consonant | 0.16±0.00 |
| Vowel duration | 0.18±0.10 |

**Table 2:** Descriptive data of mean and standard deviations for the syllable /ta/

| Acoustic Parameters /ta/ | Mean±SD |
|---|---|
| Voice onset time | 0.04±0.00 |
| Closure duration of stop consonant | 0.13±0.05 |
| Vowel duration | 0.21±0.09 |

## Discussion

The aim of the present study was to describe three features of time domain in Persian-speaking children with Down syndrome in CV units in order to increase the knowledge of therapists regarding phonetic features and differences in the quality of voice in children with Down syndrome. We determined the mean and standard deviation of the variables of voice onset time, closure duration time and vowel duration time in the / pa / and / ta / syllables. Review articles showed that in children with Down syndrome, the ability to produce diado task /pa/

and / ta / increases with age; Hence, the average duration of the studied variables decreases. For example, Sharon et al. conducted a study on the acoustic parameters of the closure duration time of consonants, voice onset time and the vowel and word duration as well as the maximum speed of iteration of syllables in the Consonant-Vowle-Consonant (CVC) context in eight unilingual English speaking children with Down syndrome (with an average age of 7 Up to 12 years). The results showed that the means of all three mentioned above durations in Down syndrome children also decreased with increasing age [18]. In Sharon's study, the mean of voice onset time, closure duration time and the vowel duration variable were 0.081, 0.083 and 0.19 respectively which were lower than those in our study [18]. Therefore, the results of the present study confirm the findings of Sharon. In the present study, the age of children was younger than the age of children in the Sharon study, so the means of the variables were higher. In another study, Rochet et al. carried out an acoustic analysis on production of vowels in CVC context in 8 Down syndrome French speakers in the age group of 19 to 34 years old, and the mean duration of vowel/a/ was 0.15, which was lower than the mean of this variable in the present study. According to the age of the participants, the results of this study were in line with Rochet's study. As the age increases, the average vowel duration also decreases [4]. In fact, it seems that people with Down syndrome in younger group (3 to 4 years old) were significantly less skilled in performing diado tasks than adults [20].

Also in the Sharon study, results between the two groups of Down syndrome showed that as age increases, variability in diado production decreases due to the maturity of motor control skills with age. In addition, in our study there is a large variation in the mean vowel duration, which confirmed Sharon's study [18]. Researchers have found that hypotonia and speech muscle control in Down syndrome patients may be a cause of the longer duration and high variability of vowel duration, because it causes deeper muscle relaxation in these individuals. Deeper speech-related muscle relaxation requires more muscle stagnation and, consequently, a higher potential for activation. This can be related to the longer duration in production. However, it seems that the reason for longer duration is related more to the muscle control than anatomical anomalies [8, 9]. In the following, some of the limitations of the diado task in these children were presented. We will also present valuable findings on the restrictions on the execution of the diado task in children with Down syndrome, which provide valuable information to therapists regarding the coordinate between the vibrations of the vocal cords in the larynx with the speech producers in the oral area. Different views and explanations have been acquired in this regard, some of which are mentioned below. Out of 10 children with Down syndrome who performed the procedure, 4 were excluded. With reference to the data obtained from the diado task of /pa/ta/, some participants produced voiceless (/ba/da/) and some produced voiced sounds (/pa/ta/). To explain, there is the lack of coordination and stability in production, i.e. the subjects could not continuously control the vibration of their vocal cords. In the same lines, some studies also reported aperiodic vibration of vocal cords measured with jittering (short-term variations in the frequency of the vibration cycle) and shimmering in these children [21, 22]. In some other syllable iterations by these four children, physiological factors such as whispered and aspirated expression of vowels were excluded from the final analysis. The aspirated production is also seen in flaccid dysarthria [19]. In subjects with Down syndrome, muscle hypotonia produces symptoms similar to the flaccid or ataxic dysarthria, and influences the function of speech production subsystems, especially the larynx, uvula and oral producers [14]. Some data could not be analyzed due to their very low resolution, and were excluded from the dataset. It has been shown in some studies that the low resolution of these subjects is due to reduced oral movement skills. In Down syndrome patients, the resolution of producing the diado of CVC context is lower than a single-word production [4, 23].

In our study, children had to iterate the CV context (/pa/ and /ta/) and the resolution of producing the diado task was low which is in line with the above studies. Although all children received the same procedure to produce voiceless consonants of /p/ and /t/, from among six final subjects, only two Down syndrome children pronounced them as /pa/and /ta/ and four others pronounced them as the voiced form of /ba/ and /da/. The other researchers also showed that the difference in the speech pattern between normal and children at ages of 3 to 6 is more pronounced; however, the difference may be shown from the beginning years [7, 20, 24]. In our study, children with Down syndrome who had errors in their production or those who pronounced /pa/ and /ta/ as /ba/ and /da/ were in the age range of 3 to 6. According to the results of the above studies [7, 20, 24] consonant substitutions in our study can be justified. Paul believes that the process of phonological processes in these children is similar to that of normal development, with the difference that these children are hindered in the acquisition of these processes and make more uses of phonological processes [25]. Consequently, in the natural development process, the consonants of /p/ and /b/ are created at about 2 or 3 years of age. There is no specific sequence for learning the /t/ and /d/ consonants and children master them at the beginning years, i.e. about 3 [19, 26].

They stated in another study that the emergence and mastering the consonants in children with Down syndrome occurs in a longer process, which is in line with Paul's study [27]. But in some other studies, contrary to the above, the speech pattern of children with Down syndrome has been shown to be a combination of developmental hindrance and disorders that are not observed in the natural development process But in some other studies, contrary to the above, the speech pattern of children with Down syndrome has been shown to be a combination of developmental hindrance and disorders that are not observed in the natural development process [23]. These children have at least one of the non-developmental disorders. One of these non-developmental patterns that does not occur in the natural

development process is frequent errors in explosive consonants), which is observed in four children we studied [28]. These phonological non-developmental errors are not necessarily observed in all subjects with Down syndrome [29].

In this study, children with the mean age of 4.9 were studied. It was impossible to provide a large sample of children with Down syndrome at this average age who were able to produce meaningless / pa / and / ta / diado task.

In future studies, however, it is recommended that acoustic variables be analyzed by producing single words in order to collect more analyzable data and to obtain more accurate results.

## Conclusion

According to the results of this study, it can be concluded that the speech time domain features in Persian-speaking children with Down syndrome were similar to these features in other languages, which could be due to problems with the tone and muscular strength in these children.

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**Conflict of Interest:** None declared.

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