SPEECH BREATHING IN CHILDREN WITH A CLEFT PALATE

Delphine Charuau[1,2], Béatrice Vaxelaire[2] & Rudolph Sock[2,3]

[1] Univ. Grenoble Alpes, Grenoble INP, CNRS, GIPSA-lab, Grenoble, France, [2] University of Strasbourg, U.R.1339 Linguistique, Langues, Parole LiLPa, Strasbourg, France, [3] Pavol Jozef Šafárik University, Language, Information and Communication Laboratory (LICOLAB), Košice, Slovakia
delphinecharuau1@gmail.com

ABSTRACT

The aim of this paper is to investigate speech breathing patterns in young speakers with a cleft palate and to examine compensatory strategies deployed at the thoracic and abdominal levels in order to compensate for supraglottal deficits. To do so, 17 control speakers and 12 children with cleft palates were recorded. The variation of respiratory movements was measured using electromagnetic thoracic and abdominal belts. The respiratory signals were synchronized with acoustic data.
Results show that compensatory strategies are mainly deployed during expiration. The compression of the rib cage is higher for children with cleft palate than control speakers. Furthermore, this strategy is amplified when velopharyngeal functionality is more severely affected. However, for inhalation, no discernible difference was detected between control subjects and children with cleft palate. Finally, statistical analyses revealed that compensatory strategies do not have a significant effect on the temporal organisation of speech in children with cleft palate.

Keywords: Speech Breathing, Children, Cleft Palate, Velopharyngeal function.

1. INTRODUCTION

Cleft palate is craniofacial malformation affecting oral and nasal structures. Despite good chirurgical reconstruction, children with a cleft palate develop speech disorders such as articulation errors, sound substitutions, among others [1], and physiological impairments like velopharyngeal insufficiency. The soft palate does not offer a hermetic closure of velopharyngeal port which leads to nasal airway emission during speech production. Consequently, there is loss of intraoral pressure [2].
Consonantal production needs high and stable intraoral pressure [3][4]. The variation of lung volume expired ensures, in part, production and stability of intraoral pressure and adapts to the aerodynamic requirements of sounds [5].
Other studies focus on respiratory movements during production of a single word [6][7]. The data show that speakers with a cleft palate and velopharyngeal insufficiency produce intraoral pressure similar to control speakers by increasing respiratory movements. These speakers compensate loss of intraoral pressure by higher pulmonary volumes.
Breathing contributes to the temporal organisation of speech, grouping words within breath groups according to linguistic rules [8][9]. Hence, the disruption of breath patterns can impair speech timing.
The aim of this study is to investigate speech breathing patterns in young speakers with a cleft palate and to examine compensatory strategies deployed at the thoracic and abdominal levels in order to compensate for supraglottal deficits. We hypothesize that children with a cleft palate deploy respiratory compensatory strategies that are manifested through increased expiratory movements to compensate for the loss of intraoral pressure related to palatal malformations. Furthermore, we hypothesize that these speakers may extend inspiratory movements in anticipation of the increased aerodynamic need for phonation compared to control speakers. Finally, the respiratory strategies deployed by children with a cleft palate could have an impact on the temporal organisation of speech, given the close relationship that exists between breathing and speech production.

2. METHOD

2.1. Speakers and Corpus

Twelve children with repaired cleft palate or cleft and lip palate, between 7 and 12 years old (mean = 9.5; sd = 1.508) were recorded. These speakers were divided into three groups: those with adequate velopharyngeal function (CP-A), a slight velopharyngeal insufficiency (CP-sVI), characterized by nasal airway emission only during the production of some sounds, and those with severe velopharyngeal insufficiency (CP-SVI), characterized by continual nasal airway emission. Diagnosis of nasal airway emission and its severity was carried out by a speech therapist. The control group comprised seventeen children between 8 and 11 years old (mean = 9.71; sd = 0.772) without cleft or lip palate and with no reported speech or respiratory disorders. All participants of this study were native speakers of French.

For the first task, children read a short sentence (on average 4 syllables per sentence) comprising a target vowel-consonant-vowel (VCV) sequence. For each sentence, consonants varied between voiceless plosives [p t k], voiced plosives [b d g], and voiceless fricatives [s] and [ʃ].

In a subsequent task, each participant was asked to read the tale *La bise et le soleil* at a comfortable speech rate and intensity. This task was repeated a second time. For the spontaneous speech task, the speakers were asked to carry out a picture-based storytelling task. An example was provided with similar images before the beginning of the recording session.

2.2. Acquisition system

The variation of respiratory movements was measured using Respiratory Inductive Plethysmography, a Respitrace system (ADInstruments). Two electromagnetic belts were placed on the thorax and the abdomen of each speaker. The acoustic data was collected using a Senheiser e835s microphone and a Marantz Professional digital recorder and synchronized with respiratory signals using PowerLab (ADInstruments). The synchronized respiratory and speech signals allow observing variations of the thoracic-abdominal perimeter during phonation.

2.3. Data processing

In order to examine the breathing movements as a whole, we created a new signal by collapsing the thoracic and abdominal signals (1 Tho + 1 Abd) [11]. The amplitude of respiratory movements was reported according to maximum displacement [14], estimated for each speaker from isovolume maneuvers [11][10].

The respiratory data was processed using MATLAB software. Temporal speech measures were carried out using Praat software [12].

2.4. Speech and respiratory measurements

The respiratory contribution was evaluated using inspiratory and expiratory amplitudes. ‘Inspiratory amplitude’ is defined as the difference between minimum and maximum values of inspiratory movement [13]. ‘Expiratory amplitude’ is defined as the difference between initial lung level and lung level at the end of a breath group. A ‘breath group’ is defined as the interval between the end of a breath pause and the beginning of the second breath pause. In reading and spontaneous speech, the duration of each breath group was measured.

2.5. Statistical analyses

Statistical analyses were conducted using RStudio software (version 1.4.1717, 2021). Data were compared using mixed measures ANOVA. Based on these measures, we were able to verify the effect of inter (groups of speakers) and intra-subject factors (target consonants, speech tasks) on the analysed variables: inspiratory and expiratory contributions (amplitude), duration of breath groups and the number of syllables per breath group. The overall significance level was calculated as $p < 0{,}05$. When significance was indicated, Bonferroni tests were conducted.

3. RESULTS

3.1. Carrier sentences

3.1.1. Expiratory contribution during consonant cycle production

In both control and cleft palate speakers, the amplitude of expiratory movements revealed to be greater during consonant cycles containing fricative voiceless consonants than those containing plosive consonants (Voiceless fricatives: CP = 6.989 %MD; Control = 4.233 %MD; Voiceless plosives: CP = 3.379 %MD; Control = 2.922 %MD; Voiced plosives: CP = 3.446 %MD; Control = 2.197 %MD). Statistical analyses revealed a significant difference between fricatives and plosives ($F(1,21) = 1.928$; $p < 0.001$). However, no significant difference was found between voiceless plosive consonant cycles and their voiced counterparts.

A mixed linear regression analysis shows that the increase in expiratory contribution was not attributable to consonant duration.

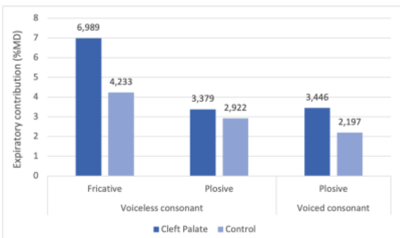

Figure 1: Expiratory contribution per consonantal cycle according to groups of speakers and target consonants.

The expiratory amplitude was found to be higher in children with a cleft palate than in control speakers, regardless of the type of consonant produced ($F(1,21) = 17.176$; $p < 0.001$). Furthermore, in children with a cleft palate, the respiratory contribution during the production of consonant cycles was observed to be greater, particularly when the velopharyngeal function is more severely affected, (i.e., when nasal airway emission is continual; see Figure 2).

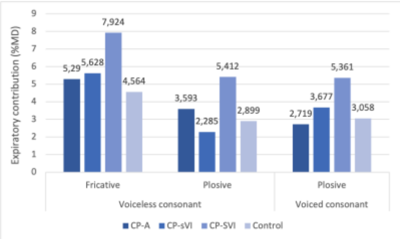

Figure 2: Expiratory contribution per consonantal cycle according to degrees of velopharyngeal inadequacy.

3.1.2. *Expiratory contribution during breath group*

Like in previous results, expiratory amplitude (Figure 3) was observed to be higher in children with a cleft palate than in control speakers ($F(1,21) = 4.610$; $p < 0.001$). Chest compression was measured on average at 28.998 %MD in children with a cleft palate and at 16.441%MD for control speakers.
Once again, expiratory movements were more exaggerated when the velopharyngeal function was severely affected (CP-SVI = 36.978 %MD; CP-sVI = 28.251 %MD; CP-A = 27.282 %MD).
However, the type of target consonant within the VCV sequence had no significant impact on the expiratory amplitude during the breath group.

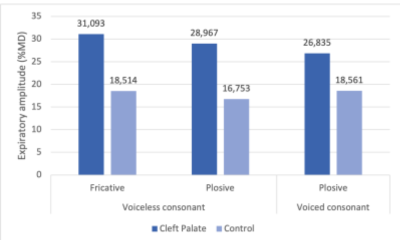

Figure 3: Expiratory contribution per breath group according to groups of speakers and target consonants.

3.1.3. *Inhalation*

Inhalation depth was similar for both groups of speakers (figure 4). While occasionally it was measured as slightly higher in control speakers, the difference was not significant.
Moreover, inspiratory contribution tends to be higher when it precedes a sentence that includes a voiceless fricative target consonant. ANOVA analyses revealed that this difference was not significant.

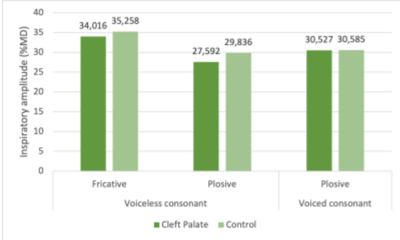

Figure 4: Inspiratory contribution according to groups of speakers and target consonants within sequence VCV

3.2. Speech breathing during read and spontaneous speech

3.2.1. *Expiratory contribution*

Expiratory movements tend to be greater in children with a cleft palate (figure 5), both in reading (CP = 26.09 %MD; Control speakers = 22.50 %MD), and in spontaneous speech (CP = 29.06 %MD; Control speakers = 24.69 %MD). Mixed measures ANOVA analyses revealed that there is no significant difference between the two groups of speakers ($F(1,21) = 0.735$; $p = 0.401$). Additionally, statistically significant differences were observed in chest compression in children with severe velopharyngeal insufficiency as opposed to control speakers (reading = 36.37 %MD; spontaneous speech = 31.21 %MD).
While expiratory movements are slightly greater in spontaneous speech for both groups of speakers, the difference was not significant.

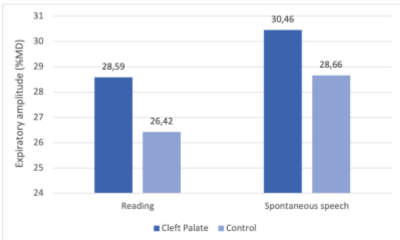

Figure 5: Expiratory contribution according to groups of speakers and speech tasks.

3.2.2. *Inhalation contribution*

As in previous results, inspiratory contribution (Figure 6) was similar between children with and without a cleft palate ($p = 0.575$), for reading (CP = 30.382 %MD; Control = 30.744 %MD) and spontaneous speech (CP = 33.242 %MD; Control = 33.978 %MD). Furthermore, the depth of inhalation tends to be greater when velopharyngeal functionality is severely affected. However, this difference is not significant ($p = 0.549$).
The speech task had a slight effect on inspiratory contribution. Inhalation depth tends to be greater in spontaneous speech for both groups of speakers.

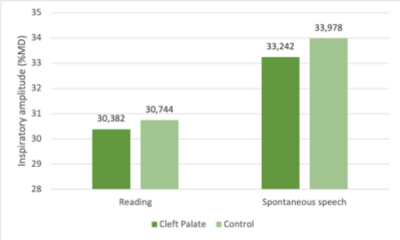

Figure 6: Inhalation contribution according to groups of speakers and speech tasks

3.2.3. Temporal organisation of speech: breath group duration analysis

In this section, we investigate the effect of compensatory respiratory strategies on the temporal organisation of speech using breath group analysis.

Breath groups tended to be shorter in children with a cleft palate than in control speakers. The difference between the two groups of speakers is not significant ($p = 0.244$). In reading, breath group durations in children with a cleft palate was measured at 2.15 seconds on average, and 2.39 seconds in control speakers. In spontaneous speech, the average duration of breath groups was 2.01 secs and 2.25 secs for children with a cleft palate and control speakers respectively.

While breath groups tend to be shorter in spontaneous speech, mixed-measures ANOVA revealed no significant effect of speech tasks on breath group durations ($p = 0.948$). Pearson's correlation coefficient indicates a partial correlation between the duration of the breath group and the expiratory contribution ($r = 0.567$; $p < 0.05$).

4. DISCUSSION

The purpose of this study was to examine compensatory strategies deployed at thoracic and abdominal levels by children with a cleft palate. Results show that these strategies were mainly deployed during the expiratory phase. The expiratory movements were greater in children with a cleft palate. Increase in the expiratory contribution allows expulsion of larger lung volumes to compensate for supraglottal deficits. This increase is more salient when velopharyngeal functionality is severely affected, like when the nasal airway emission is continual, involving a constant loss of intraoral pressure.

The expiratory contribution was higher during production of consonantal cycles containing voiceless fricatives than those containing plosive consonants. These data support those of Ohala [5], obtained from adults without speech disorders. According to Warren & Wood [15], fricative consonants need a large lung volume because their duration is generally longer than that of plosives. It should be mentioned that our results did not show any correlation between expiratory amplitudes and consonantal durations.

In reading of short sentences, whatever the target consonant, a statistically significant difference was observed in the expiratory contribution in children with a cleft palate, within the consonantal cycle. However, in text reading and spontaneous speech, these findings were confirmed only in terms of tendencies. While chest compression was also greater in children with a cleft palate, the difference was not statistically significant. These findings suggest that other factors (pragmatic, enunciative, contextual, etc.) may have an impact on the control of speech breathing.

Finally, expiratory strategies do not seem to have an effect on the temporal organisation of speech. While breath groups tended to be shorter in children with a cleft palate, this decrease does not seem to be related to an increase of the expiratory contribution during speech for these speakers. Moreover, the partial correlation between the expiratory amplitude and breath group duration suggests that other factors influence the temporal organisation of speech breathing.

As regards inhalation, no discernible difference was found between children with and without a cleft palate. Sporadically, the inspiratory movements were greater in children with severe velopharyngeal insufficiency. However, this strategy was not systematic and only appears in certain cases. The data as seen do not allow to explain the reason of such a strategy.

Given the use of expiratory strategies by children with a cleft palate, it is important that breathing be addressed during speech therapy in order to help children achieve optimal use of the breath for speech. Nevertheless, in some cases, the increase in respiratory effort can lead to an increase in audible nasal noise, which can impair speech intelligibility [7]. This study should be continued by observing the effects of these breathing strategies on sound, at the acoustic level, as well as on speech quality.

5. CONCLUSION

This study reveals compensatory respiratory strategies deployed by children with a cleft palate and their effects, to a lesser extent. Our data show that compensatory strategies are mainly deployed during expiration. Such strategies are more salient when velopharyngeal functionality is more severely affected. However, the results of reading and spontaneous speech tasks suggest that other factors are operational in the control of speech breathing.

6. REFERENCES

[1] Harding, A., Grunwell, P. 1996. Characteristics of cleft palate speech. *International Journal of Language & Communication Disorders*. 31, 331-357.

[2] Warren, D. W. (1987). Nasal emission of air and velopharyngeal function. *Cleft Palate J.* 4, 148-155.

[3] Klatt, K., Mead, J. 1968. Studies of articulatory activity and airflow during speech. *Annals of the New York Academy of Sciences*. 155, 42-55.

[4] Di Cristo, A., Teston, B. 1979. Fréquence fondamentale et pression intraorale. *Larynx et Parole.* 329-366.

[5] Ohala, J., Riordan, C., Kawasaki, H. 1980. Investigation of pulmonic activity in speech. *Investigation of pulmonic activity in Speech*. 5, 89-95.

[6] Laine, T., Warren, D. W., Dalston, R. M., Hairfield, W. M., Morr, K. E. 1989. Intraoral pressure, nasale pressure and airflow rate in cleft palate speech. *Journal of Speech, Language, and Hearing Research*. 31, 432-437.

[7] Warren, D. W., Drake, A. F., Davis, J. U. 1992. Nasal airway in breathing and speech. *The Cleft Palate-Craniofacial Journal*. 29, 511-519.

[8] Wang, Y.-T., Green, J. R., Nip, I. S., Kent, R. D., Kent, J. F. 2010. Breath group analysis for reading and spontaneous speech in Healthy adults. *Folia Phoniatrica et Logopaedica*. 62, 297-302.

[9] Winkworth, A. L., Davis, P. J., Adams, R. D., Ellis, E. 1995. Breathing patterns during spontaneous speech. *Phonetica*. 54, 138-152.

[10] Boliek, C. A., Hixon, T. J., Watson P. J., Jones, P. B. 2009. Refinement of Speech Breathing in Healthy 4- to 6-Year-Old Children. *Journal of Speech, Language, and Hearing Research.* 52(4), 990-1007.

[11] Hixon, T. J., Goldman, M. D., Mead, J. 1973. Kinematics of chest wall during speech production: volume displacements of the rib cage, abdomen, and lung. *Journal of Speech and Hearing research*. 16, 78-115.

[12] Boersma, P., Weenink, D. 2021. *Praat: Doing by computer* [Computer program]. Version 6.1.42

[13] Fuchs, S., Hoole, P., Vornwald, D., Gwinner, A., Velkov, H., Krivokapic, J. 2008. The control of speech breathing in relation to the upcoming sentence. *Proc. 8th International Seminar on Speech Production* Strasbourg, 77-80.

[14] Rochet-Capellan, A., Fuchs, S. 2013. Changes in breathing while listening to read speech: the effect of reader and speech mode. *Frontiers in Psychology*. 4, 906.

[15] Warren, D.W., Wood, M. T. 1969. Respiratory volumes in normal speech: a possible reason for intraoral pressure differences among voiced and voiceless consonants. *The Journal of the Acoustical Society of America*. 45, 466-469.