

# The Role of the Velopharyngeal Sphincter in the Speech of Patients with Cleft Palate or Cleft Lip and Palate using Perceptual Methods

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## Abstract

**Citation:** Georgievska-Jancheska T, Gjorgova J, Popovska M. The Role of the Velopharyngeal Sphincter in the Speech of Patients with Cleft Palate or Cleft Lip and Palate using Perceptual Methods. Open Access Maced J Med Sci. <http://dx.doi.org/10.3889/oamjms.2016.137>

**Keywords:** cleft palate; velopharyngeal sphincter; velopharyngeal dysfunction; Czermak mirror fogging test; PWSS.

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**Received:** 21-Nov-2016; **Revised:** 04-Dec-2016; **Accepted:** 06-Dec-2016; **Online first:** 09-Dec-2016

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**Funding:** This research did not receive any financial support.

**Competing Interests:** The authors have declared that no competing interests exist.

**BACKGROUND:** The velopharyngeal sphincter (VPS) plays the main role in speech formation. The cleft palate, due to the damage of the soft palate, leads to dysfunction of the velopharyngeal sphincter thus causing speech disorder.

**AIM:** To establish a link between the nasal air escape and the perceptual symptoms in the speech of patients with cleft palate or cleft lip and palate using auditory-visual perceptual procedures for determining the influence the velopharyngeal dysfunction has on speech.

**MATERIAL AND METHODS:** Twenty patients with speech disorders, out of which 10 have cleft palate or cleft lip and palate (experimental group), participated in the perceptual assessment by means of Czermak mirror fogging test for assessing the nasal air escape and Pittsburgh Weighted Speech Scale (PWSS) for assessing the probable nature of the velopharyngeal sphincter.

**RESULTS:** The respondents with a considerable nasal air escape have a higher velopharyngeal inability, that is, probably incompetent nature of the velopharyngeal sphincter. There is a strong correlation between the nasal air escape and the probable nature of the velopharyngeal sphincter (the coefficient of linear correlation  $r = 0.9756$ ). The calculated p-value is  $p = 0.000002$ .

**CONCLUSION:** The perceptual speech symptoms and the nasal air escape provide unique insight into the state and role the velopharyngeal sphincter has in speech.

## Introduction

The cleft palate and the velopharyngeal dysfunction can have great influence on the speech formation and the development of compensatory articulatory mechanisms [1].

In the case of cleft palate due to the damaging of the soft palate, dysfunction of the velopharyngeal sphincter (VPS) occurs, which is a three-dimensional muscle area that plays the most important role in speech formation. During speech production, the VPS separates the oral from the nasal cavity thus not allowing nasal air escape in the pronunciation of all sounds except for the nasal /M/,

/N/ and /Nj/. Speech disorders are mainly characterised by hypernasality, nasal airflow, difficulties in phonation and compensatory misarticulation [2]. Velopharyngeal dysfunction (VPD) comprises a wide scope of speech disorders [3]. According to Trost-Cardamone [4], the term velopharyngeal inadequacy can be used as a generic term for all types of velopharyngeal dysfunction. Velopharyngeal insufficiency relates to the anatomic and structural defects, while the velopharyngeal incompetence refers to the neuromotor and physiological impairments. If there is mislearning of the articulatory schemes, then it is a case of velopharyngeal mislearning. Most authors suggest the term velopharyngeal dysfunction as the most generic one.

The concept of velopharyngeal dysfunction exists theoretically; however, in clinical terms, velopharyngeal dysfunction is a diagnosis designed by perceptual symptoms in the process of speech production [5, 6]. The clinical examination of VPD begins with the evaluation of those perceptual symptoms appearing in speech production. It is important to establish the level of VPD on the qualitative and/or quantitative scale since this can offer some forecasting information and resources for following the changes through time.

This paper aims at establishing the correlation between nasal air escape and perceptual symptoms in the speech of patients with cleft palate or cleft lip and palate using auditory-visual perceptual procedures for evaluating the influence VPD has on speech. The focus of research is on the perceptual rating of the velopharyngeal function about the measurements of nasal air escape.

The most commonly used protocol for assessing the speech in velopharyngeal insufficiency among the experts from that field is that of perceptual assessment [7, 8]. Using perceptual assessment, various aspects of the speech formation are examined, including oral and nasal resonance, nasal airflow, consonantal strength/ oral air pressure and phonation in a specific context [9]. Due to their simplicity, noninvasiveness, non-technical nature and low costs of conduction, as well as fast and accurate diagnosis of VPD, auditory-perceptual examinations are of great importance for the further appropriate patient's treatment.

## Material and Methods

### Material

A total of 20 children between the age of 4 and seven were involved in this research, which was conducted in the period between September and December 2015. All the respondents have speech disorders (Dyslalia) and are divided into two groups regarding whether they have cleft palate or not. The first group (experimental group) comprises ten children with cleft palate (Palatoschisis) or cleft lip and palate (Cheilognatopalatoschisis) and speech disorders. The second, being the control group at the same time, comprises ten children without cleft palate or cleft lip and palate, but with speech disorders.

During the research period, all the respondents were given a speech therapy at the Centre for Rehabilitation of Hearing, Speech and Voice in Skopje according to the current protocol for that period. All the respondents were diagnosed with speech disorders.

### Methods

In the research, two independent auditory-visual perceptual examinations were conducted for estimating the velopharyngeal function. The first, which falls within the category of the most relevant procedures for assessing speech disorders with cleft palate and velopharyngeal dysfunction, is the mirror fogging test [1, 10]; in our case Czermak mirror fogging test [11]. This test for nasal airflow is useful for assessing the function of the velopharyngeal mechanism [12]. In addition to this, auditory-perceptual testing was conducted by means of Pittsburgh Weighted Speech Scale (PWSS [13, 14], particularly standardised for assessing the velopharyngeal insufficiency [15] and also one of the most commonly used in practice [16, 17].

### Czermak mirror fogging test

Often during the examination, speech disorders are first detected by perceptual assessment of speech quality, and one of the simpler methods used in this case is the mirror fogging test [18] (Figure 1). The technique used for administering the mirror fogging test which, at the same time, determines the level of nasal airflow is Czermak mirror fogging test [19].

For this test, a rectangular mirror with dimensions 10.5 cm x 17.5 cm was used. The mirror was not marked or graded. The mirror itself is used for visual indication of the nasal airflow.



Figure 1: Administering the mirror fogging test

Practically, the procedure starts by placing the mirror horizontally under the patient's nose on the columella. Then, the patient pronounces test sounds, syllables and words. If fogged circles appear in the mirror, there is a sign of nasal airflow, thus implying velopharyngeal insufficiency which is considered as a positive result. According to the Czermak's test, depending on the size of the fogged circles appearing in the mirror, Figure 2, nasal air escape is ranged on a 4-grade scale, starting with 0 – no, 1 – small, 2 – medium up to 3 – large nasal air escape. When the result is a medium nasal air escape, the velopharyngeal insufficiency is important, and

hypernasality can be heard. If there is no fogging of the mirror, the result is marked as negative (normal result).



Figure 2: Rating the degree of the respondent's nasal air escape evaluated with the Czermak's test

The examination using Czermak's test practically consists of ranging assessment on eight items, Table 1. They are divided into items for testing hypernasality (non-nasalized and less nasalized vowels) and items for nasal airflow (the respondent is asked to blow, repeat words containing plosives and voiceless consonants, and say the fricative /S/ prolonged). The result for each item is determined by applying the semi-objective interpretation of the largeness of the fogged surface using Czermak's test. The final result of the patient's nasal air escape represents the highest score obtained with the rating.

Table 1: The items used for prospective ratings of hypernasality (1-3) and nasal airflow (4-8) using Czermak's test for assessing nasal air escape

Item	Non-existent (0)	Small (1)	Medium (2)	Large (3)
1. A				
2. E				
3. O				
4. the respondent is asked to blow				
5. Pa-Pa-Pa				
6. Kapa				
7. Kate kupi kaput.				
8. prolonged /S/				
Result (highest grade)				

In this way, the results from a 4-graded rating can be compared with the results from confirmed speech analysis systems, such as the Pittsburgh Weighted Speech Scale (PWSS).

**Pittsburgh Weighted Speech Scale (PWSS)**

Pittsburgh Weighted Speech Scale (PWSS), Table 2, is a standardized method for auditory-perceptual assessment and one of the most commonly practiced methods used for rating the velopharyngeal insufficiency on a quantitative scale. This scale uses a standardised system of points that rate five speech components mainly noticeable in patients with velopharyngeal insufficiency: nasality, nasal emission, facial grimace, phonatory characteristics and compensatory misarticulations. Each component contains several items to which a varying weighted score has been ascribed. The overall score is a sum of the highest score for each component, except for the component articulation

where the score represents a sum of all the scores for each separate item. The obtained score enables patients to be classified according to their velopharyngeal competency. If the established result is 0, there is a velopharyngeal competency; 1-2 means limited velopharyngeal competency, while 3-6 means limited velopharyngeal incompetency and 7 and above velopharyngeal incompetency.

Table 2: Pittsburgh Weighted Speech Scale (PWSS). The weighted score for speech symptoms connected to velopharyngeal insufficiency

	Right	Left
Nasal air emission (0-3, highest score)		
Not present	0	
Inconsistent, Visible	1	
Consistent, Visible	2	
Nasal escape on nasals appropriate	0	
Reduced	0	
Absent	0	
Audible	3	
Turbulent	3	
Facial grimace (0/2, presence)		
Absence of facial grimace	0	
Presence of facial grimace	2	
Nasality/ resonance (0-4, highest score)		
Normal	0	
Mild Hypernasality	1	
Moderate Hypernasality	2 (-3)	
Severe Hypernasality	4	
Mixed: Hyponasality - Hypernasality	2	
Cul de Sac	2	
Hyponasality	0	
Phonation / voice (0-3, highest score)		
Normal	0	
Hoarseness or Breathiness		
Mild	1	
Moderate	2	
Severe	3	
OR:		
Reduced Loudness	2	
Tension in System	3	
Other:		
Articulation (0-23, cumulative)		
Normal	0	
Developmental Errors	0	
Errors from other causes not related to VPI	0	
Errors related to anterior dentition	0	
Reduced intraoral pressure for the sibilants	1	
Reduced intraoral pressure for other fricatives	2	
Reduced intraoral pressure for plosives	3	
Omission of fricatives and plosives	2	
Omission of fricatives or plosives plus hard glottal attack for vowels	3	
Lingual Palatal sibilants	2	
Pharyngeal fricatives, plosives, backing, snorts, inhalations, or exhalation substitutions	3	
Glottal stops	3	
Nasal substitutions for pressure sounds	4	
	<b>Total score</b>	
Probable nature of the velopharyngeal sphincter		
- velopharyngeal competency	0	
- borderline velopharyngeal competency	1-2	
- borderline velopharyngeal incompetency	3-6	
- velopharyngeal incompetency	7 and up	

For the administration of the PWSS test, were used sounds (A; E; O), syllables (Ma-Ma-Ma-Ma; Na-Na-Na-Na; Pa-Pa-Pa-Pa; Ta-Ta-Ta-Ta; Ka-Ka-Ka-Ka), words (Saat; Shuma; Drvo; Fustan; Zhaba) and sentences (Simo se smee; Shana shie koshula; Rade pere motor; Kate kupi kapa; Tode vide dete).

**Statistical analysis**

The results from both conducted tests, Czermak mirror fogging test and Pittsburgh Weighted

Speech Scale (PWSS), were expressed in numbers. Afterwards, the results were statistically processed, graphically presented and descriptively analysed.

By using the data analysis software system STATISTICA version 7.1. [20], statistical analysis of the obtained results was carried out, and calculation of the coefficient of linear correlation  $r$  and  $p$ -value (probability value) was made.

## Results

Twenty respondents with speech disorders, 10 of which comprised the experimental group and had cleft palate or cleft lip and palate (having previously undergone surgery for correcting the cleft), participated in conducting the auditory-visual perceptual assessment for determining the level of nasal air escape and probable nature of the velopharyngeal sphincter. A total number of 20 respondents underwent the examination, seven boys and 13 girls, with a mean age of 5 and a half years (between the age of 4 and 7). In the experimental group, made up of 10 participants, 6 participants had cleft palate – Palatoschisis, and four cleft lip and palate – Cheilognatopalatoschisis. The ten respondents in the control group had no cleft palate or cleft lip and palate at all.

The results from the assessment of the level of nasal air escape using Czermak’s test are presented in Table 3. The mean score for all the respondents for that test is 1.1 (scope 0-3), thus indicating a small level of nasal air escape.

**Table 3: Visual-perceptual assessment of nasal air escape – Czermak mirror fogging test**

Respondent	Result (0-3, highest score)	Not present (0)	Small (1)	Medium (2)	Large (3)
Experimental group					
1	3			2	3
2	1	0	1		
3	3				3
4	3				3
5	1		1		
6	1	0	1		
7	3				3
8	2		1	2	
9	1		1		
10	2			2	
Control group					
11	0	0			
12	1		1		
13	0	0			
14	0	0			
15	0	0			
16	0	0			
17	1	0	1		
18	0	0			
19	0	0			
20	0	0			
Mean score	1.1				
Scope	0-3				

The mean score for the experimental group is 2 (scope 1-3), meaning there is a moderate level of nasal air escape, and what was noticeable for every

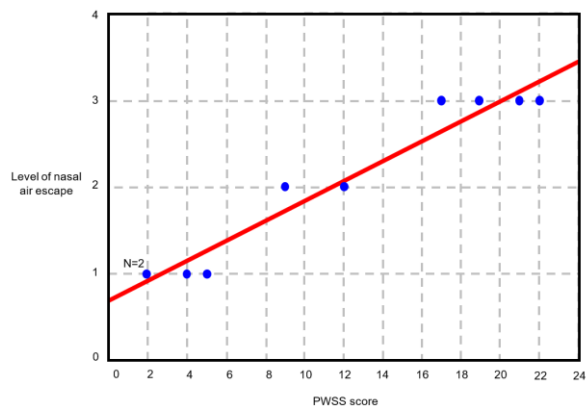
respondent was mirror fogging, that is, the presence of nasal air escape during speech.

The mean score for the PWSS test is 5.8 (scope 0-22) which shows that for all the respondents the probable nature of the velopharyngeal sphincter is limited velopharyngeal incompetency, Table 4. The established mean score for the experimental group is 11.3 (scope 2-22) denoting that the probable nature of the velopharyngeal sphincter is velopharyngeal incompetency. 80% of the experimental group characterises with limited velopharyngeal incompetency and velopharyngeal incompetence, thus leading to more severe pathology in the verbal communication.

**Table 4: Auditory-perceptual assessment of speech – Pittsburgh Weighted Speech Scale (PWSS)**

Respondent	Total score	Nasal air emission (0-3, highest score)	Facial grimace (0/2, presence)	Nasality (0-4, highest score)	Phonation (0-3, highest score)	Articulation (0-23, cumulative)
Experimental group						
1	17	3	2	2	3	7
2	4	0	2	0	1	1
3	21	2	2	4	3	10
4	22	3	0	4	3	12
5	2	0	0	1	0	1
6	2	0	0	0	2	0
7	19	3	0	4	2	10
8	9	2	2	1	2	2
9	5	1	0	1	2	1
10	12	3	2	2	2	3
Control group						
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	1	0	0	0	1	0
14	1	0	0	0	0	1
15	0	0	0	0	0	0
16	1	0	0	0	0	1
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
Mean score	5.8					
Scope	0-22					

Pearson coefficient of correlation (the coefficient of linear correlation) is used for assessing the correlation between the results obtained from the Czermak mirror fogging test and PWSS test. The correlation was made only between the results obtained from assessing the experimental group, Figure 3, since the result for the control group is zero except two cases where it is 1.



**Figure 3: Correlation between the score from the PWSS and level of air nasal escape**

The changes in the probable nature of the velopharyngeal sphincter are in close correlation with the changes in the level of nasal air escape, and there is a strong correlation between the two ( $r = 0.9756$ ). Since there is a positive value for  $r$ , it can be concluded that when the first variable increases, so do the second. The calculated p-value is  $p = 0.000002$ .

## Discussion

The children with cleft palate or cleft lip and palate show dysfunction of the velopharyngeal sphincter, and this leads to the pathology of verbal communication. Regardless of the size of the cleft, the articulatory speech is hindered due to the constant communication between the oral and nasal cavity. The core of the speech disorder lies in nasality that is, dragging part of the air through the nose while speaking due to the incomplete closure of the palatopharyngeal sphincter, which is insufficient contact between the soft palate and the rear wall of the pharynx. The situation can be more complicated and with hindered articulation. For diagnostic and therapeutic purposes, it is important to determine the nasal air emission and the level of dysfunction of the velopharyngeal sphincter. A suitable treatment of the velopharyngeal dysfunction depends on the precise interpretation of the perceptual and physiological characteristics the respondent possesses.

The results obtained from the two assessed variables in this paper, the level of nasal air escape and the probable nature of the velopharyngeal sphincter largely differ between the respondents with cleft palate or cleft lip and palate and speech disorders (experimental group) and the respondents with speech disorders only (control group). The higher values of the two assessed variables for the experimental group suggest bigger velopharyngeal opening. Looking in greater detail, it would be said that for the experimental group the overall PWSS score is in strong correlation with the level of nasal air escape. Clinically, this means that the respondent with severe perceptual speech symptoms, the stereotype of velopharyngeal insufficiency, shows a higher level of nasal air escape thus suggesting bigger velopharyngeal opening.

Because there is no a single study in literature which enables the results from the level of nasal air escape and probable nature of the velopharyngeal sphincter to be compared, the comparison with other studies was very difficult to be made, or it was limited. Still, a certain number of authors, one of which is Scarmagnani et al. [21], points out that there is a considerable correlation between the size of the velopharyngeal closure and the level of nasal air escape in patients with a corrected cleft palate which,

in fact, overlaps with the result from our research. However, unlike this research, Scarmagnani uses various researching methods (aerodynamic speech assessment and audio-digital speech recording) and different statistical analysis (Spearman's rank correlation coefficient). On the other hand, the results obtained by Kummer et al. [22] suggest that hypernasality (with or without nasal emission) can be primarily connected with the relatively large velopharyngeal opening. In our research, the results revealed a direct positive connection between the level of nasal air escape and velopharyngeal dysfunction. Therefore, the greater the nasal air escape is, the bigger the velopharyngeal dysfunction is which is also acknowledged by Abou-Elsaad et al. [23].

There is also an overlap of the results from our research and those obtained from the research conducted by Gubrynowicz et al. [11] where the Czermak's test is used and reveals greater nasal emission due to the wide opening of the velopharyngeal opening. By experimenting with patients with a cleft who previously underwent palatoplasty, but in this case a larger and different age group than in our research, Dudas et al. [2] obtained results which show limited or completely incompetent velopharyngeal closure. There is an 80% overlap between those results and ours obtained from the PWSS test.

This research has a few limitations worth mentioning. First, further research should include a larger number of respondents so that obtained results would have greater relevance. Second limitation is that during the intraoral examination the presence of cleft (cleft palate or cleft lip and palate) was established, but not its size as well (for instance, by using the Veau Classification), nor how the size of the cleft affects speech. That is, how it affects the level of nasal emission or perceptual speech symptoms. Future research should include these aspects as well.

Knowing that certain aspect of speech are directly related to velopharyngeal anatomy, perceptual speech symptoms and nasal air escape provide unique insight into the status and role the velopharyngeal sphincter has in speech.

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