

Children with obstructive sleep disorder demonstrate altered oral and nasal airflow in syllable reading task

Lei He¹ Huiping Luo²

¹*Institute of Modern Languages and Linguistics, Fudan University, Shanghai, China*

²*ENT institute and Department of Otorhinolaryngology, Eye & ENT Hospital, Fudan University, China*

The obstructive sleep disorder is a prevalent condition among children, between two and eight years of age in particular. The principal etiology of this complication involves the hypertrophy of adenoid and/or palatine tonsils as a result of recurrent immune stimulation. The hypertrophy causes blockage in key sites including the nasopharynx and oropharynx in the upper airway. During sleep in the supine position, both enlarged tissues and gravity combine to obstruct the airway, leading to snoring, hypopnea, and apnea. Prolonged obstructive sleep disorder in children without timely and correct interventions can result in serious consequences, such as neurocognitive and behavioral deficits, cardiovascular complications, growth failures, and craniofacial abnormalities, which may also lead to atypical pathways to speech, language and cognitive development [1–5].

In addition to reduced ventilation, upper airway obstructions may also disrupt speech production, as the nasopharynx and oropharynx constitute critical junctions in the vocal tract (see Fig. 1 for an illustration). This points to the possibility to use acoustic analysis of speech as a tool for evaluations and diagnoses. While endoscopic and radiological techniques are indispensable to reach a confirmed diagnosis, speech acoustic analysis can offer a quick and non-intrusive supplement, making it ideal for initial ambulatory assessments and triage. Involving speech scientists in evaluation and decision-making aligns with the modern medical paradigm of the Multidisciplinary Team (MDT) meeting. For this exploratory, prospective cohort study, we analyzed whether variations in the oral and nasal airflows in syllable reading task are significantly different between the group of children with obstructive sleep disorder and the comparison group of healthy children.

We recruited a group of 21 children with obstructive sleep disorder (adenoid and/or palatine tonsil hypertrophy), and the same number of healthy children as the comparison group (7 $\pm$ 2.4 years of age). They were required to produce 144 syllables, which are classified into four categories: V (single vowel), NV (nasal consonant + vowel), VN (vowel + nasal consonant) and NVN (nasal consonant + vowel + nasal consonant).

We used the Glottal Enterprises NVS system which simultaneously recorded the airflow pressures at the nasal and oral exits. For each of the nasal and oral airflow during the production of each syllable, we calculated the windowed RMS values to constitute the airflow time series. Two types of variations were calculated for each intensity curve, coefficient of variation (*cv*) and time-dependent instantaneous curvedness (*curv*). The algorithm for the *curv* has been described in [6] on the complexity of f_0 curves, but the mathematics remains the same. Altogether four numeric variables were calculated: *cv_nasal*, *cv_oral*, *curv_nasal* and *curv_oral*. For each syllable category (V, NV, VN and NVN), we fitted a mixed-effect binary logistic regression model, where *group* (pathol vs healthy) was modeled as the dichotomous response variable, and the four intensity variables were fitted as regressors. As all participants produced the same set of syllables, individual syllables were modeled as random effects.

The variance inflation factors (VIFs) for the four regressors (*cv_nasal*, *cv_oral*, *curv_nasal*, and *curv_oral*) were all below 5. This confirmed that multicollinearity was within tolerance, thereby supporting the inclusion of all variables in model building. All variables have been tested to be significant in explaining the difference between pathological and healthy groups for all syllable categories, demonstrating that nasal and oral airflow variations during syllable production are promising indicators of pediatric obstruction in the upper airway leading to sleep disorders. Table 1 includes details of statistical results.

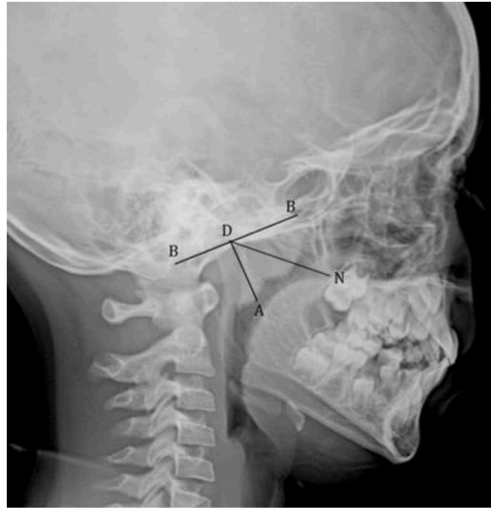


Fig. 1. A plain X-ray image demonstrating an enlarged adenoid tonsil occupying the nasopharynx and oropharynx junction in the vocal tract [7]. BB = straight part of anterior margin of basiocciput; AD = adenoid depth; ND = nasopharyngeal depth.

Table 1. Summary of statistical results; intercepts are omitted. (**P < 0.001, *P < 0.01, *P < 0.05).

Syllable category	Numeric variables	β	se	z
NV	ln(curv_nas)	0.46497	0.08732	5.325***
	ln(curv_oral)	-0.33841	0.11280	-3.000***
	ln(cv_nas)	-2.52140	0.18956	-13.301***
	ln(cv_oral)	3.69704	0.21819	16.944***
NVN	ln(curv_nas)	0.27871	0.07147	3.900***
	ln(curv_oral)	-0.54191	0.10313	-5.255***
	ln(cv_nas)	0.33233	0.15886	2.092*
	ln(cv_oral)	1.59704	0.19608	8.145***
V	ln(curv_nas)	0.4558	0.1366	3.336***
	ln(curv_oral)	-0.3931	0.1212	-3.244**
	ln(cv_nas)	-3.8816	0.3331	-11.653***
	ln(cv_oral)	4.5656	0.3024	15.098***
VN	ln(curv_nas)	0.17333	0.7467	2.321*
	ln(curv_oral)	0.48713	0.07063	6.897***
	ln(cv_nas)	-0.70171	0.14192	-4.944***
	ln(cv_oral)	0.30235	0.12812	2.360*

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