Submitted: 04 March, 2024 Accepted: 27 May, 2024 Published: 03 January, 2025 DOI:10.22514/jocpd.2025.014

ORIGINAL RESEARCH

Journal of Clinical Pediatric Dentistry

An experimental clinical study on measurement methods of children's oral respiration

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Abstract

Background: This controlled clinical trial investigated the spirometry sensitivity for screening mouth breathing. Mouth breathing in children may cause abnormalities in dental and maxillofacial development, and even have adverse impact on physical and mental health. At the same time, there is no unified standard for outpatient diagnosis of oral breathing between pediatricians and dentists. It is thus clinically important to explore conducive diagnostic method for children's oral respiration in outpatient multidisciplinary clinic. **Methods**: A total of 48 children and adolescents of 6–14 years age attending the Department of Stomatology in Hebei General Hospital were selected for oral and nasal respiration examinations by the conventional clinical methods. Slow ventilation was then improved with the MasterScreen PFT (Pulmonary Function Instrument) system in respiratory clinic. Patients were allowed to take several calming breaths after the relaxation. Patients' tidal volume and oral airflow during the inhalation were subsequently measured using thoracic motion measurements as a reference. It was determined whether the children were mouth-breathing or not. The data were statistically analysed. **Results**: The differences in tidal volume and oral airflow were statistically significant for oral-breathing group ($p < 0.05$). The differences in nasal-breathing group were not significant. Results of the modified spirometer usage and clinical examination of mouth breathing children were similar. **Conclusions**: Modified lung function instruments quickly determine the presence and severity of children's mouth breathing. It is suggested that the oral respiratory airflow testing by this method along with the four conventional methods to detect severity of oral respiration can improve the diagnostic and therapeutic accuracy.

Keywords

Mouth breathing; Children and adolescents; Experimental study; Oral breathing airflow

1. Introduction

Mouth breathing is one of the most common deleterious oral habits in children and a symptom of sleep disordered breathing. The prevalence of this condition ranges from 11 to 56% in children [1, 2]. As well as the etiology and classification include obstructive mouth breathing, long-term oral bad habits, and anatomical factors. Obstructive mouth breathing is more common in children and is one of the symptoms of obstructive sleep apnea hypoventilation syndrome in children [3]. Prolonged mouth breathing can cause changes in the three-dimensional direction of dental and maxillofacial growth and development [4]. The characteristic facial features such as high arched hard palate, narrow dental arches, anterior lip inclination, and short and thick lips [5, 6]. Therefore, dentists should pay attention to children's oral breathing [7].

There is no unified standard for diagnosing oral breathing at domestic and international levels, which has been among the reasons for increased difficulty in standardized treatment [8]. The common clinical methods for detecting oral respiration in children are as follows: Questionnaire survey such as OSA (Obstructive Sleep Apnea)18 [9]; Lip closure test [10]; Double sided mirror test below room temperature [10]; Water content test: Child's mouth has 10–15 mL water maintained for 3 min [8]; and Cotton wool test. These methods can have errors because of variety of techniques and experiences made by doctors. They thus lead to decreased experimental accuracy [11]. Furthermore, these qualitative tests cannot determine the severity of oral breathing. Mouth breathing can thus be diagnosed by the methods which quickly measure the proportion of mouth breathing. Polysomnography (PSG) is the "gold standard" to diagnose obstructive sleep apnea-hypopnea syndrome (OSAHS) in children [12]. However, the device can detach in children and adolescents during the night sleep, which has impact on numerical accuracy [13].

Yang Kai [14] proposed a new mouth and nose airflow synchronous measurement system. It measures the total airflow through mouth and nose masks, as well as the changes in chest

and abdominal outer diameters by using chest and abdominal air belts. Moreover, their functional relationships are found via the linear regression. The nasal airflow rate and changes in outer diameters of chest and abdomen are recorded at this time. Breath flow rate is obtained by subtracting the nasal airflow rate from total airflow rate measured for the second time. The proportion of oral and nasal airflow are thus determined.

Polysomnography (PSG) [15] diagnoses sleep snoring (Obstructive Sleep Apnea-Hypopnea Syndrome), and determines the children sleep condition. Physicians obtain more accurate information of child's mouth breathing and judge its severity. The device may fall off during children night sleep which affects the determination of final value and leads to uncertain results. A simple and rapid measurement method is thus required to provide guidance data for the clinicians. Hua Xing *et al*. [16] improved the usage method of lung function instrument by measuring patient's tidal volume and oral airflow. It determines patient's oral breathing and its severity. There are two pathways for tidal airflow, *i.e.*, oral and nasal. First, when patient is calmly breathing, clamp the nasal clip and hold the mouthpiece to measure tidal volume. Then, release the nasal clip and measure flow rate through breath. The tidal volume is equal to nasal exhalation volume and oral breathing volume for measuring the proportion of oral breathing. The characteristics of our hospital are combined by using existing pulmonary function equipment (MasterScreen PFT System, CareFusion, Free State of Bavaria, Germany), designing improved methods, and measuring the proportion of oral respiratory airflow. This method can help improve the diagnosis in the clinic.

The doctor's clinical observation method can only be qualitative because of the limited medical knowledge of patient's parents. The patient's half-open-mouth when one is quiet does not necessarily indicate mouth-breathing. Therefore, a simple and convenient method was designed to measure the transtracheal flow volume of mouth breathing patients. Furthermore, this study was designed to demonstrate that modified spirometry method could be accurate than clinical screening methods.

2. Materials and methods

A Total of 48 children and adolescents aged 6–14 years were selected from the Department of Stomatology at Hebei General Hospital. 48 children were divided into two groups. According to the gender ratio of the local population, each group selects 13 boys and 11 girls. All of them came to clinic with mouth opening problems (Table 1).

TABLE 1. Gender distribution.

	Boys	Girls	Total
Oral breathing	13	11	24
Non oral breathing	13	11	24
Total	26	22	48
Percent	54.2	45.8	100.0

Exclusion criteria: (1) Those undergone adenoid and tonsil surgery. (2) Treated for oral breathing. Inclusion criteria: (1) Children are aged 6–14 years. (2) The main complaint of parents is open mouth breathing. (3) Children have a face of open lips and teeth.

First, mouth breathing was assessed through four traditional methods, *i.e.*, common scale OSA-18 (Questionnaire scores greater than 60 is positive, less than 60 is negative), low-temperature double-sided mirror test, cotton wool test, and water content test (longer than 3 minutes is negative, less than 3 minutes is positive). Their scores were recorded. Four positive methods were considered of the oral respiratory group, while 0 to 2 positive methods of nasal respiratory group. However, they were grouped as per the severity of OSA-18, when three methods were positive. It was included in the nasal respiratory group with negative questionnaire, while in the oral respiratory group with positive questionnaire. Therefore, 24 children were recorded in the oral respiratory group and another 24 in nasal respiratory group (Table 1).

Second, One MasterScreen PFT System pulmonary function test was conducted on 48 children (Fig. 1). Methods such as listening to music and reading were used to keep them in calm breathing state. The chest movement during this time was recorded by measuring tape. A segment of data was observed and recorded when waveform was stable. We designed two scenarios to measure a patient's total tidal volume and oral respiratory airflow. The first method of measuring total tidal volume was to use a nasal clamp, where all airflow passes through the tubes in the mouth (Fig. 2), In the second scenario, release the nasal clip and measure the oral respiratory airflow under natural breathing mode (Fig. 3). These two pictures from a doctor's test and have obtained informed consent. The oral breathing ratio was equal to oral airflow/tidal volume. Each group was measured in triplicate. First three times were the tidal volumes during calm breathing with nasal clip on, and the normal use of spirometers. They were recorded as A1 for mouth-breathing patients and A2 for nose-breathing patients. Last three times were based on the spirometers usage without nasal clip on. The transthoracic airflow data for mouth-breathing patients were recorded as B1 and oral airflow data for nose-breathing patients as B2. Two measurements were taken for each patient to achieve same thoracic mobility, and act as reference for ensuring equal ventilation volume and reduce errors.

SPSS (IBM SPSS Statistics23, IBM Corporation, Armonk, NY, USA) software was used as the statistical tool. Paired *t*-tests were conducted after taking the average of data measured in four scenarios. A p-value < 0.05 was considered for determining statistical significance.

3. Results

The difference between two groups of data was statistically significant upon comparing tidal volume A1 with mouth-breathing volume B1 of mouth-breathing patients (Tables 2,3).

The normal calm breathing displayed fluctuating curve on computer after the mouth breathing patient released the nose clip (Fig. 4). The nasal breathing patient displayed calm straight line after the nose clip was released (Fig. 5). So, the oral air flow rate of nasal breathing patient B2 was not

FIGURE 1. MasterScreen PFT System, pulmonary function instrument (CareFusion, Germany). Technical parameters: (1) Flow rate capacity sensor (high-quality digital) (range (0 ± 20) L/s, accuracy (0.2–12) L/s (±2%), resolution 10 mL/s, resistance <0.05 kPa/L/s); (2) Capacity (built-in software with digital integration method analysis) (range 0–20 L, accuracy (±50 mL, ±3%), resolution 1 mL); Several supporting mouthparts, and 1 desktop computer.

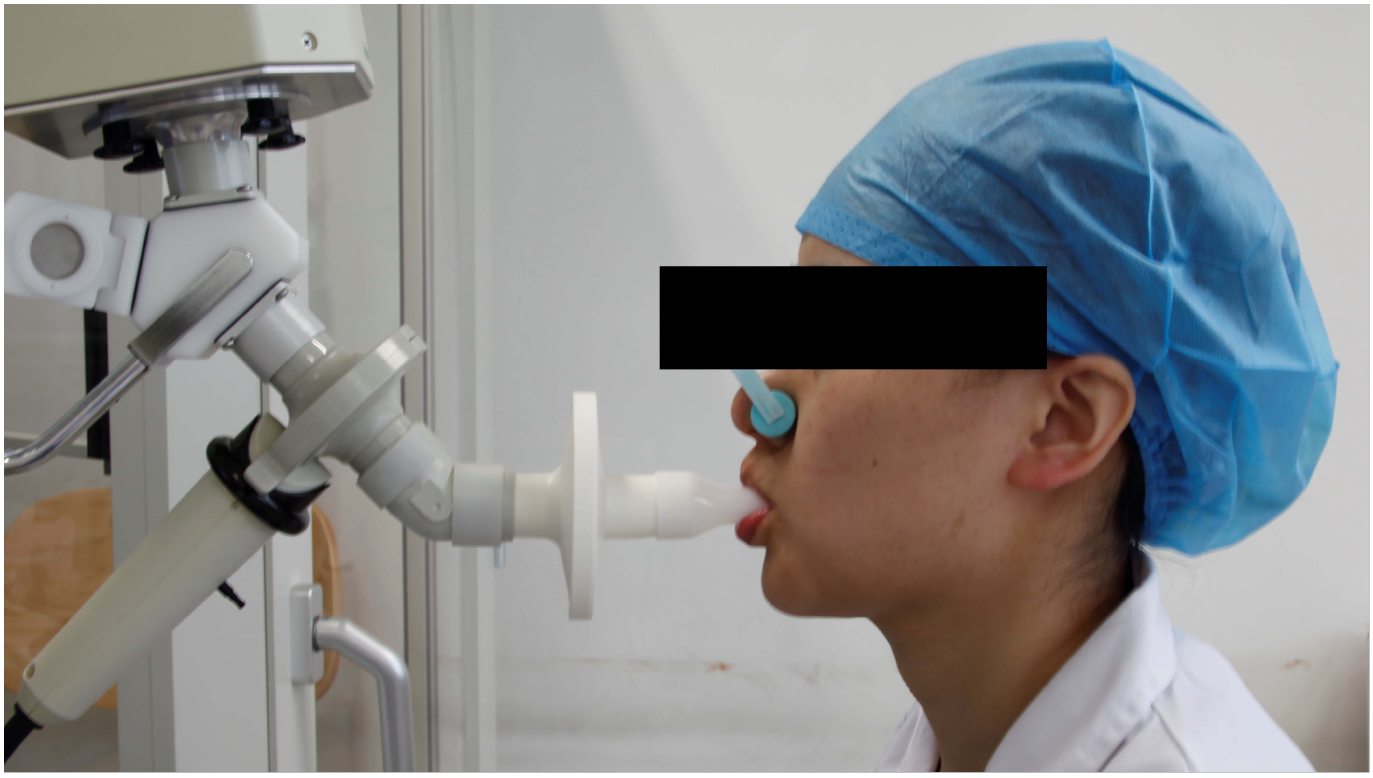

FIGURE 2. Tidal volume with upper nasal clamp.

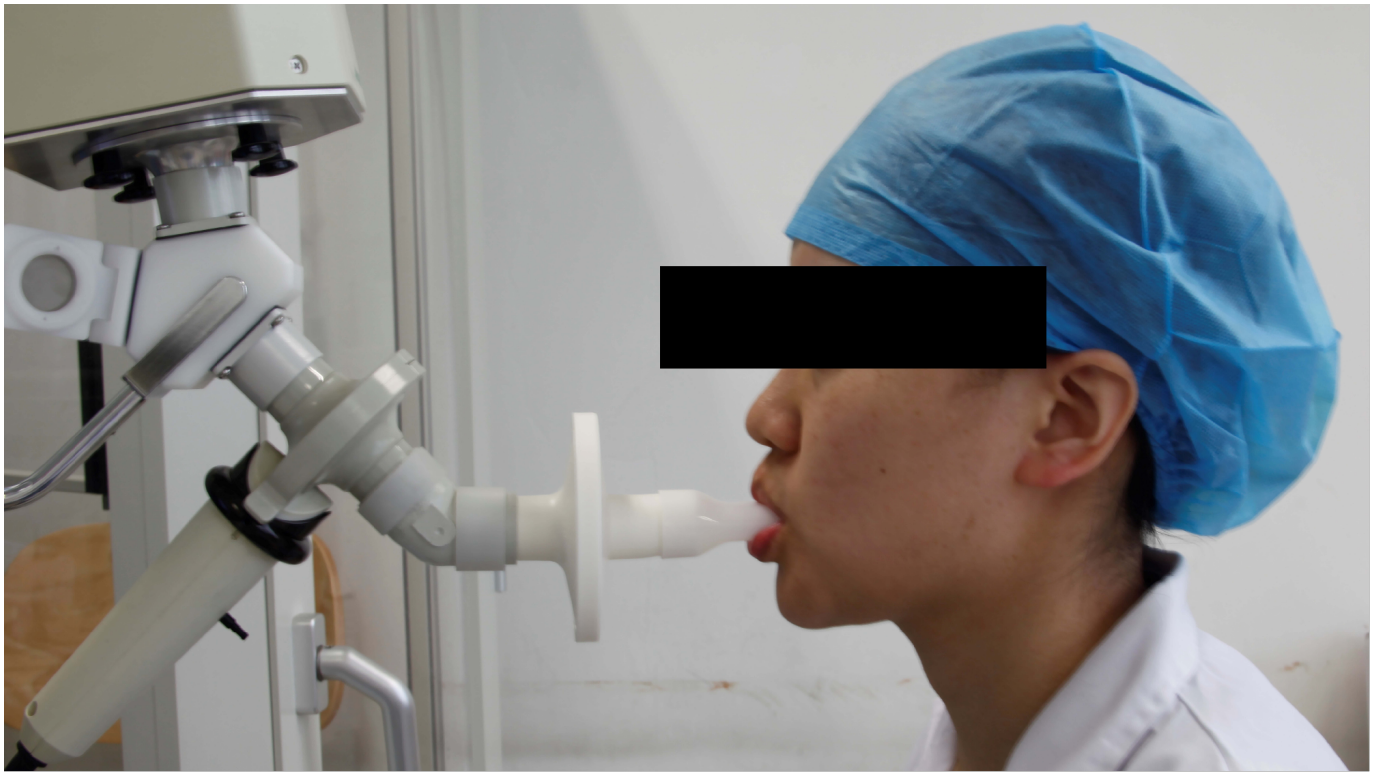

FIGURE 3. The nasal clamp released and measured oral breathing airflow.

TABLE 2. Paired sample statistics.

Group	Mean	Standard deviation	Mean standard error	Number
Pair1				
A1	0.500	0.197	0.040	24
B1	0.349	0.183	0.037	24
Pair2				
A2	0.487	0.225	0.046	24
B2	0.000	0.000	0.000	24

statistically significant.

After testing with the pulmonary function instrument, there were 2 children (3 positive methods) in the routine test of oral breathing group with oral breathing ratio of <25%. The data were included in nasal breathing group. In the routine test, one person in nasal breathing group (also 3 positive methods) was included in breathing group with mouth breathing ratio of 35%.

4. Discussion

Significance of outpatient testing for measuring mouth-to-mouth breathing ratio: Results show that the use of modified spirometer is similar to the outcomes of clinical examination. It more accurately screens mouth breathing and the proportion of mouth breathing in children.

Inspired by the research of other scholars on oral respiratory airflow devices [14, 16], we have improved the usage of lung function instruments. Measurement results show certain errors in the scoring methods of survey questionnaires, low-temperature double-sided mirrors, water content test, and cotton wool test, especially when the results are positive in three methods. The mouth and nose airflow measurement device can accurately measure the ratio of mouth breathing [15]. We have enhanced the utilization of the outpatient lung function instruments, which can also quickly and easily determine the oral respiration ratio. When nasal clamp is not used for measuring oral breathing airflow, the patient has oral breathing if continuous and stable breathing waveforms and data records appear on computer. The patient has no oral breathing airflow if patient's waveform is recorded as straight line. This method calculates mouth breathing ratio by, mouth breathing ratio = oral airflow/tidal volume. It is considered mouth breathing if the ratio exceeds 30%. Therefore, the quantitative measurement of oral respiratory airflow by lung function instrument, combined with the traditional examinations, and scoring five methods together, are significant for the evaluation of respiratory abnormalities in children and adolescents of outpatient clinics, followed by the selection of treatment methods. PSG examination is feasible with obvious symptoms of pediatric OSAHS or when surgical indications are needed.

There are many advantages to conducting rapid oral breathing testing in such outpatient clinics. For example, simple and non-invasive operation, high cooperation among children, and easy acquisition of instruments and equipment, convenient data acquisition, high repetition rate of experimental data, and low cost. At the same time, there are some shortcomings of the method. The nervousness and lack of cooperation by children can affect the data which require experienced physicians to assess the respiratory data effectivity. A comfortable temperature environment for the patient needs to be ensured. An interval between each set of measurements is required so that

TABLE 3. Paired *t*-test data of 48 mouth and nose breathing patients.

Group	Mean	Standard deviation	Mean standard error	95% confidence interval		*t*	*p*
				lower bound	upper bound		
A1-B1	0.150	0.104	0.021	0.107	0.194	7.106	<0.001
A2-B2	0.487	0.225	0.046	0.392	0.581	10.619	<0.001

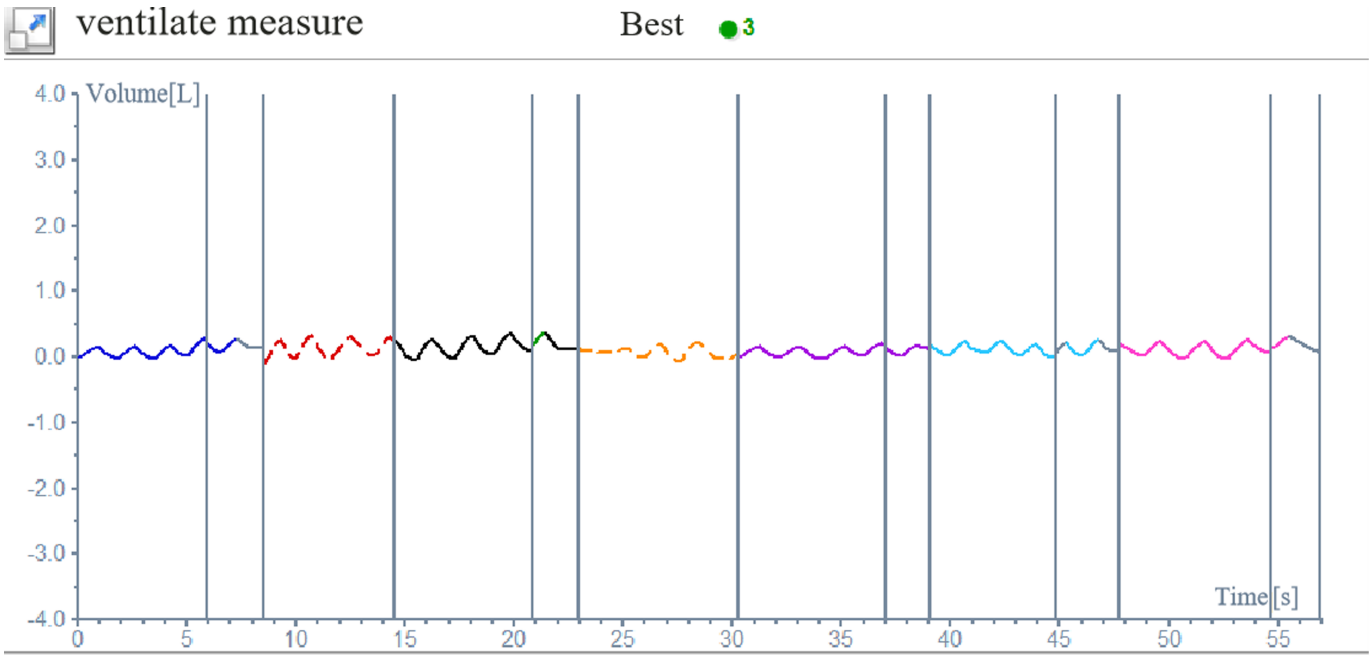

FIGURE 4. Oral respiration: the amount of breath from mouth.

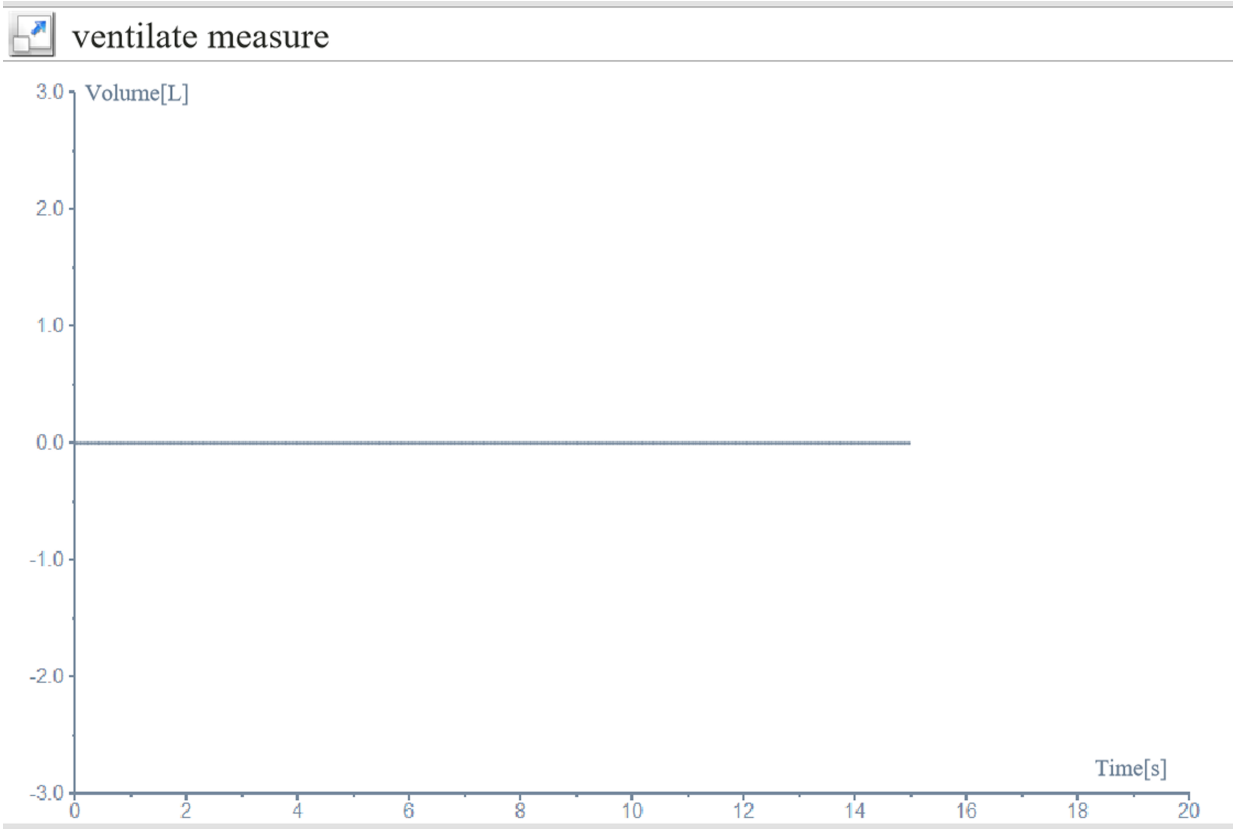

FIGURE 5. Nasal breathing: the amount of breath from mouth.

the patient is relaxed before the next set of tests are performed. Measurements are stopped immediately if abnormalities are found in the experiment. The causes of abnormalities are identified and measured again. The child's nervousness is eliminated, breathing waveform abnormalities are avoided, and errors of multiple timed measurements are reduced by letting the child listen to music, meditate, and inform before next steps.

Studies suggest that if the airflow passes through the mouth and exceeds 25–30% [17], it is considered as oral breathing, and if all the airflow passes through the mouth, it is considered severe mouth breathing. As early as 1872, scholars proposed that adenoid hypertrophy can cause airway obstruction, forcing children to open their mouths and breathe, affecting the normal development of the maxillofacial region and leading to malocclusion, adenoid facial features [18–20]. In addition to causing dental and maxillofacial deformities, oral breathing can also affect children's learning ability, healthy development, and quality of sleep and life [21]. Oral breathing treatment involves multiple departments such as otolaryngology, pediatrics, and dentistry [22]. It is imperative to identify related systemic diseases like obstructive sleep apnea syndrome caused by adenoid and tonsil hypertrophy [7, 23]. Reflexive oral breathing may occur if the airway is blocked to certain extent. It is a physiological reflex activity where in body expands the upper airway [24]. Adenoid and tonsil hypertrophy can cause sleep apnea and hypoventilation syndrome in children, leading to abnormal craniofacial development [25]. For Children with OSAHS with adenoid and tonsil hypertrophy and no contraindications for surgery, glandular thyroid and tonsillectomy are the preferred treatment methods [26–28]. The removal of upper airway obstruction factors does not necessarily mean the end of treatment, and orthodontic treatment is still needed for the dental and maxillofacial deformities that have already formed in the child [29]. Early diagnosis and regular follow-up are crucial for timely detection and management of recurrent adenoids [30].

Healthy individuals can also experience partial oral breathing under specific physiological conditions such as exercise and heavy mental labor, which increase the nasal airflow speed. Treatment is necessary when oral breathing reaches certain frequency and degree which may impact the function [7]. Oral breathing is also caused by bad habits [31]. Some children still have oral breathing after the removal of nasal airway obstruction. Children with no upper airway obstruction are also accustomed to open mouth breathing [32]. It is vital to timely block and leave bad habits. Functional appliances such as vestibular shields and lip guards can be used [7]. The insufficient lip muscle strength and inability to close the lip can be treated by lip muscle training exercises or with muscle function training equipment [33].

Early detection and diagnosis of oral breathing in children and adolescents followed by timely and personalized treatment can reduce malocclusion, and its impact on facial function and overall health [34]. There is no unified standard for the diagnosis and treatment of children's oral breathing at domestic and international levels. Studies have revealed that the incidence rate of mouth breathing detected by different methods is not consistent [35]. Costa *et al.* [36] found that orthodontists have poor breathing recognition in young population by comparing orthodontists and otolaryngologists. Meanwhile, research has shown that male and female children with malocclusion are more likely to experience oral breathing [37]. This requires attention for identifying symptoms and risk factors of pediatric OSAHS in outpatients. This all is based on the accurate diagnosis of mouth breathing at early stage, and avoiding over diagnosis and delayed treatment. It is thus important to improve the devices for efficient measurement of proportion of children's mouth breathing in outpatient clinics.

5. Conclusions

Modified lung function instruments quickly determine the presence and severity of children's mouth breathing. It is suggested that the oral respiratory airflow testing by this method along with the four conventional methods to detect severity of oral respiration can improve the diagnostic and therapeutic accuracy. And it's convenient for children who go to outpatient clinics.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

LLX—designed the research study. LLX and YNM—performed the research, wrote the manuscript. LGL—provided help and advice, analyzed the data. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The manuscript was approved by the Ethics Committee of Hebei General Hospital. The approval number as NO. 2023180. All images have obtained informed consent. This research was conducted with the informed consent of the children's parents or legal guardians.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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How to cite this article: Lili Xie, Yanan Ma, Liguo Li. An experimental clinical study on measurement methods of children's oral respiration. Journal of Clinical Pediatric Dentistry. 2025; 49(1): 136-142. doi: 10.22514/jocpd.2025.014.