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The Respiratory Rehabilitation Effect and Mechanism of Action of Oscillating Positive Expiratory Pressure Devices

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Abstract: Chronic respiratory diseases are one of the major global health problems, and their treatment and management impose a huge burden on both patients' quality of life and healthcare resources. Respiratory rehabilitation, as a non-pharmacological treatment, has received increasing attention in recent years. Oscillating positive expiratory pressure (OPEP) devices, as a new type of respiratory rehabilitation device, show good application prospects in improving respiratory function, promoting sputum expectoration, and improving quality of life. The purpose of this paper is to review the effect and mechanism of OPEP in respiratory rehabilitation.

Keywords: Oscillating positive expiratory pressure; Respiratory rehabilitation; Chronic obstructive pulmonary disease

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1. Introduction

Respiratory diseases are one of the leading causes of death and disability worldwide, with the prevalence and mortality of chronic respiratory diseases still increasing [1]. Chronic obstructive pulmonary disease (COPD), asthma, bronchiectasis, cystic fibrosis, and other diseases share the common features of airway obstruction and excessive mucus secretion, leading to symptoms such as dyspnea, cough, and sputum, which seriously affect patients' quality of life. Respiratory rehabilitation, as a non-pharmacological treatment, aims to improve respiratory function, increase respiratory muscle strength and endurance, enhance lung capacity and lung ventilation, promote lung clearance of sputum, prevent respiratory infections, allowing patients to better cope with respiratory diseases or rehabilitation after injury, and improve their respiratory efficiency and quality of life, by means of a series of training and activities [2]. An oscillating positive expiratory pressure (OPEP) device is a new type of respiratory rehabilitation device, through which active exhalation can produce

positive expiratory pressure and oscillatory airflow, which acts on the airways, promotes mucus loosening and collateral circulation, and improves pulmonary ventilation, thus achieving the purpose of improving airway clearance function and relieving respiratory symptoms [3]. Compared with traditional respiratory rehabilitation methods, OPEP devices exhibit the advantages of simple operation, high safety and effectiveness, good patient compliance, and wide application scenarios, demonstrating good results in clinical application.

2. Overview of respiratory rehabilitation

2.1. Definition and objectives of respiratory rehabilitation

Respiratory rehabilitation is a comprehensive intervention aimed at improving the physical and social functioning of patients suffering from chronic respiratory diseases. Its goals include: (1) improving respiratory function, including lung function, respiratory muscle strength and endurance, etc.; (2) reducing dyspnea and other respiratory symptoms; (3) enhancing exercise endurance and the ability to perform activities of daily living; (4) improving psychological well-being and quality of life; and (5) reducing the number of hospitalizations and medical costs.

2.2. Indications and contraindications of respiratory rehabilitation

Respiratory rehabilitation is applicable to a variety of chronic respiratory diseases, including COPD, cystic fibrosis, bronchiectasis, interstitial lung disease, postoperative recovery from lung cancer, and respiratory dysfunction caused by neuromuscular diseases. These diseases often require comprehensive rehabilitation to improve respiratory function and quality of life. Although respiratory rehabilitation is beneficial in most cases, there are some contraindications, notably unstable cardiovascular disease, acute respiratory infections, and severe mental disorders. In these cases, performing respiratory rehabilitation may be risky and therefore requires special caution.

2.3. Common methods and techniques of respiratory rehabilitation

There are various methods and techniques for respiratory rehabilitation, mainly including:

(1) Exercise training: This includes aerobic exercise (e.g., walking, swimming) and resistance training (e.g., weight lifting, elastic band training), aiming to improve cardiorespiratory function and strengthen respiratory muscles, and to help patients improve physical strength and respiratory efficiency.

(2) Breathing training: Techniques such as abdominal breathing and lip-constriction breathing are used with the aim of optimizing breathing patterns, improving lung ventilation and gas exchange efficiency, and helping patients manage dyspnea more effectively.

(3) Airway clearance techniques: Techniques such as postural drainage and vibratory expectoration, aim at removing secretions from the airway, reducing airway obstruction, and improving the patient's respiratory fluency.

(4) Nutritional support: This supports overall health and recovery of respiratory function by improving the patient's nutritional status and enhancing the body's resistance and recovery.

(5) Psychological support: This provides psychological counseling and emotional support to help patients alleviate anxiety and depression, and improve their knowledge and ability to manage their illnesses, thereby enhancing their quality of life.

3. Introduction to OPEP

3.1. History of OPEP

Oscillating positive expiratory pressure is a new type of respiratory rehabilitation equipment, and its development history can be traced back to the 1980s. Early OPEP devices were mainly used to treat airway obstruction in cystic fibrosis patients. With the advancement of technology and the promotion of clinical application, OPEP devices have been gradually applied to the treatment of other respiratory diseases and achieved good results.

3.2. Working principle of OPEP

Oscillating positive expiratory pressure is a non-invasive respiratory therapy device used to improve respiratory function. Unlike some other respiratory therapy devices that actively provide airflow, the OPEP device itself does not generate airflow, and when patients can actively exhale through the device, the exhaled airflow is resisted by a special structure inside the device, which generates positive expiratory pressure and oscillatory airflow. These act on the respiratory tract, and their working principle mainly includes the following aspects (**Figure 1**):

(1) Promoting mucus loosening and removal: The oscillating airflow can be delivered to the deeper part of the airway, generating shear forces that loosen mucus attached to the airway wall and expel it with exhalation.

(2) Promoting collateral ventilation: Positive expiratory pressure can open the collapsed small airways, increase collateral ventilation, and improve gas exchange in the lungs.

(3) Improving lung ventilation: Positive expiratory pressure can prevent premature airway trapping, prolong expiratory time, increase alveolar emptying, and improve lung ventilation.

(4) Synergistic effect: The synergistic effect of oscillatory airflow and positive expiratory pressure can effectively remove airway secretions and improve respiratory muscle function, thus enhancing the patient's respiratory function.

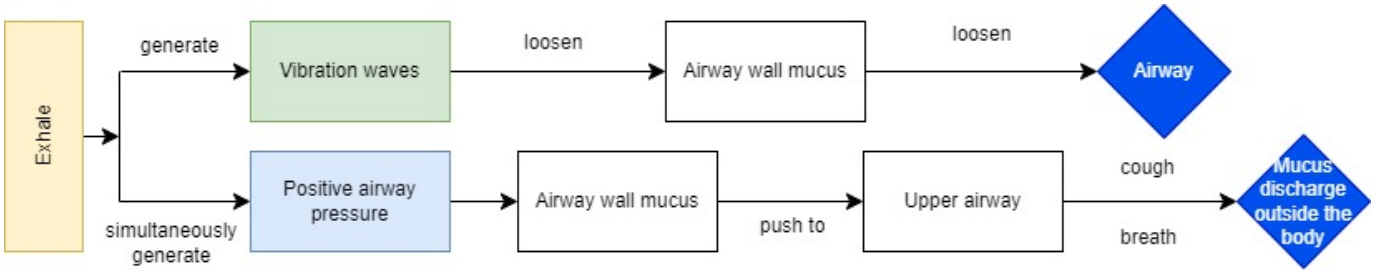

Figure 1. Workflow diagram of OPEP

3.3. Classification and characteristics of OPEP

According to the different ways of vibration frequency and pressure adjustment, OPEP equipment can be divided into two main types:

(1) Fixed-frequency and pressure OPEP devices: The vibration frequency and pressure of such devices are set to fixed values, which are easy to operate, less expensive, and suitable for basic therapeutic needs.

(2) Adjustable frequency and pressure OPEP devices: These devices allow the frequency and pressure of vibration to be adjusted according to the patient's condition, thus providing a more personalized

treatment effect, and are suitable for patients who require more precise adjustments.

4. Mechanism of action of OPEP

4.1. Mechanism of oscillating airflow to promote airway secretion clearance

The oscillating airflow generated by the OPEP device has the following effects: (1) Reducing airway resistance: The oscillating airflow causes the gas molecules in the airway to move at high speed, thus reducing airway resistance and improving gas exchange. (2) Diluting secretion: Oscillating airflow can change the rheology of mucus, so that the secretion in the airway can be coughed up more easily, helping to clear the airway. (3) Enhancing cilia movement: Oscillating airflow stimulates the movement of cilia in the airway, promotes the accelerated discharge of secretions, and improves the self-cleaning ability of the airway. (4) Promoting collateral circulation: When the oscillating airflow flows in the airway, it produces certain pressure changes and stimulation to the tissues around the airway, thus promoting collateral circulation around the airway. The improvement of side branch circulation helps to increase local blood supply and oxygen delivery and improve the metabolism and repair ability of the airway mucosa. (5) Preventing airway collapse and prolonging expiration: During normal expiration, the pressure in the airway decreases, which tends to lead to narrowing and collapse, especially in patients with respiratory diseases. The positive pressure effect of the oscillating airflow maintains the airway open and ensures smooth expiration. Due to the short normal expiratory time, some secretions may not be expelled in time. Oscillatory airflow prolongs the expiratory time and increases the airflow residence time in the airway, thus facilitating the expulsion of secretions. At the same time, prolonging the expiratory time reduces the end-expiratory lung volume, reduces the residual gas in the lungs, and improves the lung ventilation function [4].

4.2. Effects of oscillatory positive pressure expiration on lung function

The OPEP device significantly improves lung function through oscillatory positive pressure expiration [5,6], and its main effects are as follows:

(1) Enhanced lung volume and one-second rate: OPEP equipment can significantly enhance the patient's lung volume and one-second rate, which indicates that the ventilation function of the lungs has been improved, making the patient's breathing more efficient.

(2) Improved lung compliance: OPEP device helps to improve lung compliance, making it easier for the lungs to expand and contract during inhalation and exhalation, which improves the overall elasticity and function of the lungs.

(3) Improved oxygen saturation: OPEP devices also increase oxygen saturation, indicating improved gas exchange, which results in higher levels of oxygen in the blood, thus improving the oxygen supply to the tissues.

5. OPEP product design and technical features

Oscillating positive expiratory pressure device adopts advanced vibration technology and ergonomic design with the following technical features:

(1) Adjustable oscillation pressure and frequency: By adjusting the size of the airway orifice, the oscillation frequency and pressure generated can be changed and selected according to individual comfort and

therapeutic needs. It is usually recommended that the patient's expiratory flow rate be 30–50 L/min or more to ensure that an effective airflow and pressure are generated, and the specific requirements may vary depending on the model of the device and the individual differences of the patient.

(2) Compact and portable design: The device design is compact and lightweight, making it easy for users to carry and use.

(3) Non-electricity dependent: No batteries or power supply is required for operation, increasing portability and flexibility of use in a variety of environments.

(4) User-friendly: Simple design makes it easy for users to operate on their own. Equipped with easy-to-understand manuals, cleaning guides, and video tutorials to assist with exercise, ensuring that users can use and clean it properly.

(5) Economical: Compared to other technologies that may require expensive equipment or repeated purchases, this product is a one-time purchase that can be used repeatedly.

(6) Simple to maintain: Steps including rinsing and cleaning with water, soaking in boiling water for five minutes to sterilize, and drying for spare parts help to maintain hygiene and prevent the build-up of bacteria.

5.1. Product advantages and application scopes

5.1.1. Product advantages

The OPEP device has the following product advantages:

(1) Wide range of applications: It is suitable for a variety of conditions requiring airway clearance, including but not limited to COPD [7], cystic fibrosis, asthma, and bronchiectasis.

(2) Significant clinical benefits: Regular use of the OPEP device significantly improves the user's respiratory function, reduces the risk of respiratory infections by effectively clearing airway secretions, and builds airway wall muscles.

(3) Enhanced patient autonomy: Purely physical expectoration supports home treatment, giving patients greater independence and better management of their respiratory status.

5.1.2. Application scopes

The device has a wide range of applications in the rehabilitation training of respiratory diseases, especially in assisting sputum expulsion. Applicable diseases include:

(1) Heart diseases: E.g. heart failure, coronary artery disease, rehabilitation after cardiac surgery, post cardiac transplantation, cardiac arrhythmia, and pulmonary hypertension. These diseases may result in limited respiratory function, and the device can help improve airway patency and promote sputum expulsion.

(2) Asthma: Used in the rehabilitation of asthma patients, it helps to reduce airway inflammation and improve respiratory function, relieving symptoms.

(3) Airway diseases: Including bronchiectasis, tracheal stenosis, inflammatory diseases of the airways, and tracheal motility dysfunction. The device can help remove secretions in the airway and alleviate the condition.

(4) Ear, nose, and throat (ENT) disorders: Such as enlarged tonsils and adenoids, perioperative nasopharyngeal cancer, snoring, and obstructive sleep apnea syndrome. The device can assist in alleviating related breathing problems and improving breathing conditions.

(5) Lung diseases: Such as COPD, lung infection, interstitial lung disease, pulmonary thromboembolism, and tuberculosis. The device effectively promotes expectoration and improves lung function.

(6) Chest surgery: Such as pulmonary nodule resection, heart valve replacement surgery, heart bypass surgery, and other chest surgeries. Post-surgical application can effectively eliminate secretions in the lungs and prevent postoperative pulmonary complications.
(7) Hepatobiliary and pancreatic diseases: Including liver cirrhosis, liver cancer, or pancreatic cancer in the perioperative period, as well as pulmonary complications caused by hepatobiliary and pancreatic diseases. The device helps to alleviate pulmonary symptoms.
(8) Gastrointestinal diseases: Such as perioperative gastric cancer, perioperative colon cancer, and gastrointestinal-related resections. The device can help manage postoperative pulmonary complications and promote recovery.

5.2. Clinical application effect

The clinical data of 888 patients who used the OPEP developed by a medical technology (Hangzhou) Co. Ltd. for respiratory rehabilitation were collected and analyzed, and it was found that the device had been applied in a number of hospitals, accumulating a large amount of clinical data. The study showed that this OPEP device can effectively improve the lung function of patients with COPD, cystic fibrosis, bronchiectasis, and other respiratory diseases, reduce the number of acute exacerbations, improve exercise tolerance, and significantly improve the quality of life.

6. Safety and precautions for OPEP

6.1. Potential risks and contraindications of OPEP

The OPEP device is safe, but there are still some potential risks and complications, such as (1) Dizziness: Some patients may experience dizziness at the beginning of using the OPEP device, which usually disappears after a period of adaptation. It may be related to hyperventilation. (2) Pneumothorax: In rare cases, the use of OPEP devices may lead to pneumothorax, especially in patients with large herpes in the lungs. (3) Ear discomfort: Some patients may experience ear discomfort when using OPEP devices, which may be alleviated by adjusting the position of use or reducing the frequency of vibration. In addition, the OPEP device is contraindicated in patients with active tuberculosis, hemoptysis, pneumothorax, severe cardiovascular disease, and inability to cooperate with treatment. Other contraindications include undrained pneumothorax, hemodynamic instability, increased intracranial pressure, recent maxillofacial surgery or trauma, suspicion or presence of active hemoptysis, or tympanic membrane rupture.

6.2. Methods and precautions for OPEP use

In order to ensure the safe and effective use of OPEP equipment, the following matters should be noted: use under the guidance of a professional physician, select the appropriate vibration frequency and pressure according to the medical advice; read the product instructions carefully before use, keep the equipment clean and hygienic; if any discomfort occurs, stop using it immediately and consult a physician.

The method of use is as follows:

(1) Deep inhalation: The patient inhales slowly through the nose and fully inhales.
(2) Smooth exhalation: The patient needs to exhale at a sufficient flow rate, resisting slight resistance to exhalation and using the abdominal muscles at a slightly faster rate than normal, exhale smoothly

through the OPEP for 3–4 seconds or longer, exhale fully but do not forcefully hold the breath. Vibration between 10–25 Hz can be produced under the device.

(3) Inhalation/exhalation ratio: The ratio is 1:3 or 1:4, repeated for 10–15 times (one cycle). The number of times is adjusted according to the patient's sputum volume, fatigue, and dyspnea.

(4) Stabilizing the cheek: If necessary, the cheek can be stabilized with the other hand during exhalation to ensure better exhalation of airflow.

(5) Performing several "huffs" or effective coughs to remove secretions after applying the device, for 3 to 6 cycles, depending on the amount of airway secretions.

OPEP can be combined with ACBT (Active Cycle of Breathing Techniques), which usually consists of the following steps:

(1) Breathing control: The patient relaxes the shoulders and upper chest and performs gentle tidal breathing through the nose, usually 3–4 times.

(2) Thoracic expansion exercise: The patient performs a deep inhalation and attempts to hold the breath for 3–4 seconds, then exhales slowly and repeats 3–5 times. This phase can help loosen secretions.

(3) Forceful exhalation technique: The patient performs 1–2 forceful exhalation or puffing movements after normal inhalation in order to promote the loosening and expulsion of secretions.

According to the characteristics of OPEP, OPEP can be applied to the forceful exhalation phase of ACBT to promote the removal of sputum. An example of illustration is shown in **Figure 2**.

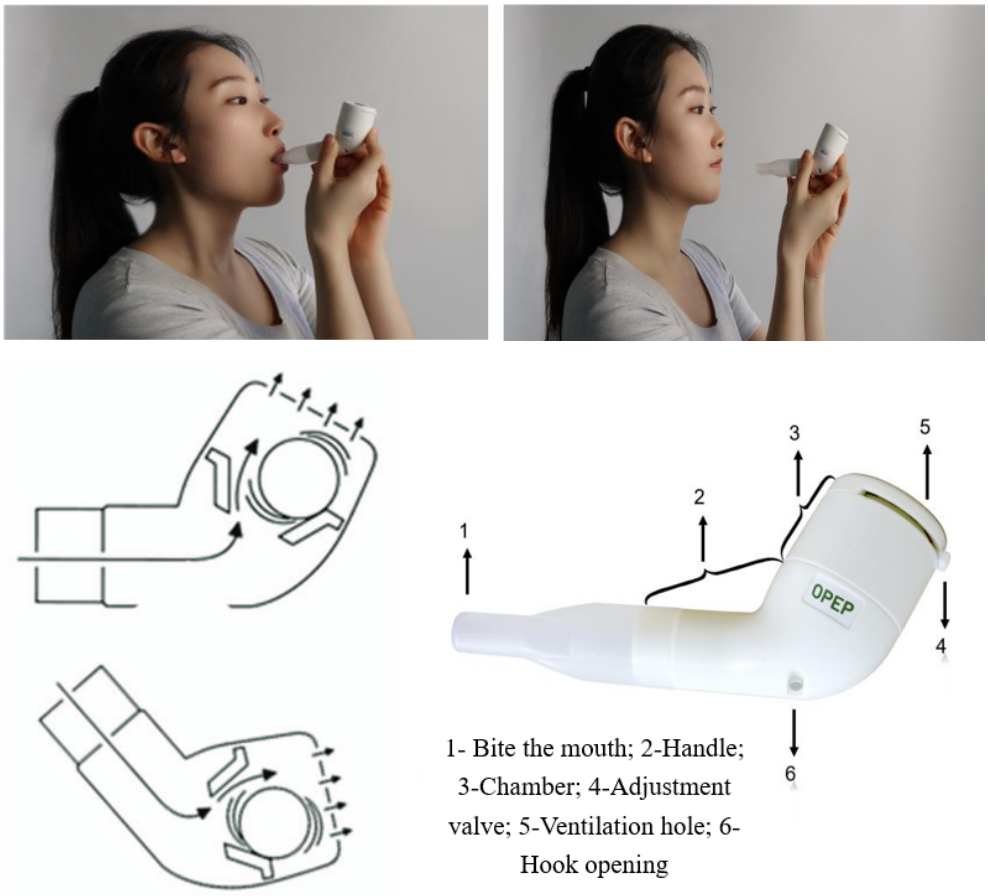

Figure 2. Illustration of OPEP use

7. Conclusion and prospects

As a safe, effective, and convenient respiratory rehabilitation tool, OPEP has shown good application prospects in the treatment of many respiratory diseases. With technological advances and clinical promotion, OPEP devices are expected to bring benefits to more patients. Future development directions include: combining it with respiratory chronic disease management, as a common rehabilitation tool for home treatment; personalized treatment, providing customized solutions based on individual differences through intelligent devices, such as precise adjustment of oscillation frequency, amplitude, expiratory resistance, and other parameters; telemedicine, combining OPEP devices with remote technology to realize remote monitoring and guidance, in order to improve the efficiency of treatment; as well as the application of new materials and technologies, such as the use of novel biomaterials and nanotechnology, to develop safer, more comfortable, and efficient devices.

Disclosure statement

The authors declare no conflict of interest.

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