

Progress in the Study of Respiratory Muscle Training on the Recovery of Swallowing Disorders Post-Stroke

Shiqi Chen¹, Wei Deng¹, Hongyan Xi¹, Jingmei Wang^{2,*}

¹Nursing College, Yunnan University of Traditional Chinese Medicine, Kunming, Yunnan, 650000, China

²Department of Neurology, Yunnan University Affiliated Hospital, Kunming, Yunnan, 650000, China

*Corresponding author

Keywords: Respiratory Muscle Training; Swallowing Disorders; Stroke; Physiological Mechanism

Abstract: Normal swallowing requires the close coordination of respiratory movements. Effective respiratory movements can reduce the occurrence of swallowing disorders. Respiratory muscle training can enhance the strength and endurance of the respiratory muscles, alleviate respiratory fatigue, and improve the coordination between respiratory movements and the swallowing process. This article summarizes the physiological characteristics related to respiratory muscles and swallowing, the mechanism of action of respiratory muscle training, and the application value of respiratory muscle training in swallowing disorders, aiming to provide a theoretical basis for studying the relationship between respiratory muscle training and post-stroke swallowing disorders.

Stroke is a chronic cerebrovascular disease characterized by high incidence, high mortality, high disability rate, and significant economic burden, often leading to various degrees of critical physiological dysfunction in patients^[1,2]. According to the "China Stroke Prevention and Treatment Report 2020," the total number of stroke patients in China ranks first in the world^[3], with about 29%-81% of patients developing swallowing disorders in the short term^[4]. Since the swallowing process and respiratory movements are regulated by various nerves and organs^[5-8], patients with post-stroke swallowing disorders often experience a coordination disorder between breathing and swallowing, increasing the risk of aspiration, aspiration pneumonia, respiratory infections, etc., severely threatening their rehabilitation progress and quality of life^[9]. Respiratory muscle training not only improves the respiratory efficiency of the body but also provides a good physiological basis for the auxiliary and compensatory processes of swallowing^[10], enhancing the swallowing function of patients after stroke. This article reviews the improvement of swallowing function disorders in stroke patients through respiratory muscle training, providing a reference for related research and clinical nursing practice.

1. Changes in Swallowing Function in Patients after Stroke

1.1 Concept and Staging of Normal Swallowing

Normal swallowing refers to the process by which food is safely and unobstructedly transported from the mouth to the stomach, involving a series of complex physiological reflexes^[11]. The entire process is functionally divided into four stages^[12]: the oral preparation stage where food is chewed to form a bolus; the oral stage where the bolus is moved to the pharynx by the movement of the tongue; the pharyngeal stage requires a brief pause in breathing with the cooperation of respiratory muscles to rapidly propel the bolus from the pharynx into the esophagus—this stage is the most critical in the swallowing process, with most swallowing disorders occurring here^[13]; and the esophageal stage, where the bolus is transported into the stomach, this stage's swallowing process is completed by esophageal peristalsis, independent of central nervous control.

1.2 Concept of Swallowing Disorders and Their Manifestations at Different Stages

Swallowing disorders refer to the impairment of functions of the lips, tongue, soft palate, jaw, pharynx, and esophageal sphincter, resulting in the inability to safely and smoothly transport food from the mouth to the stomach^[14], often related to neurological dysfunction caused by disease, muscle wasting, and imbalances in bodily functional states^[15], a common complication of stroke. It leads to aspiration, coughing, aspiration pneumonia, respiratory infections, etc^[16-18]. Depending on the obstructed site of food transportation, swallowing disorders can manifest differently if they occur at different stages of the oral preparation stage, oral stage, pharyngeal stage, and esophageal stage^[19]: In the oral preparation stage, disorders include weakness of the lip muscles, tongue muscles, chewing muscles, cheek muscles, palate, and pharynx, difficulty in opening the mouth and chewing, poor perception of food texture, food spillage, drooling, etc^[20]; oral stage manifestations include restricted lip closure, reduced mobility of the mouth, difficulty in initiating or prolonged initiation time of swallowing movements, and decreased overall coordination^[21]; pharyngeal stage manifestations include poor coordination of the muscles responsible for swallowing movements, abnormal closure of the laryngeal cavity, narrowed range of epiglottis retroflexion, delayed swallowing reflex, leading to clinical manifestations such as coughing, food stasis, and varying degrees of difficulty in speaking^[22,23]; esophageal stage manifestations include abnormal esophageal peristalsis or spasms, failure of the cricopharyngeal muscle to relax, food reflux, vomiting, etc^[24,25]. Whether swallowing function disorders occur in any single period or are concurrent obstructions in multiple periods, they pose significant physiological challenges to patients, preventing the smooth completion of the entire swallowing action.

1.3 Pathological Mechanisms of Swallowing Disorders Due to Different Brain Regions Being Affected

Cortical damage, cerebral hemisphere damage, and medullary damage can all cause swallowing disorders. Research by Rubesin et al^[26] shows that cortical damage leads to a decrease in pharyngeal muscle contractility and weakened strength of the lower esophageal sphincter, resulting in delayed initiation or inability to initiate swallowing movements. Swallowing disorders caused by cerebral hemisphere damage vary in probability and severity depending on the damaged hemisphere. Research by Zhang Jing et al^[27] indicates that after damage to the right cerebral hemisphere, the pharyngeal stage of swallowing function is mainly affected, with patients experiencing more frequent food retention in the pharynx, aspiration, and penetration; while swallowing function during the oral stage is more likely to be affected after left cerebral hemisphere damage. The swallowing centers on both

sides of the medulla contain a large number of neurons and nerves that manage swallowing functions together. Depending on the side of the damage and the affected nerves, the pathological mechanism of swallowing disorders caused by medullary damage may be related to obstruction in the opening of the upper esophageal sphincter (UES), insufficient elevation of the larynx, leading to aspiration, epiglottis residue, food leakage, etc^[28,29]. Changes in swallowing function and the stages of swallowing action are closely related to the damaged parts of the body, allowing for targeted rehabilitation training for the affected muscle groups and nerves connected to each stage and damaged area, thereby improving swallowing function.

2. The Mechanism of Action of Respiratory Muscle Training

2.1 Concept of Respiratory Muscle Training

Respiratory Muscle Training (RMT) refers to exercises that impose a certain degree of resistance to the respiratory muscles, aimed at enhancing the efficacy of both inspiratory and expiratory muscles, strengthening respiratory function, and improving the ventilation and air exchange conditions of the lungs. Studies have shown^[30] that respiratory muscle training can increase patients' Forced Expiratory Volume in the first second (FEV1), Forced Vital Capacity (FVC), the forced expiratory flow at 25%-75%, lung capacity, and Maximum Voluntary Ventilation (MVV). Conducting respiratory muscle training for a duration of 8 weeks can increase more than 90% of the predicted Maximum Inspiratory Pressure (MIP) and the strength and endurance of the inspiratory muscles in stroke patients.

2.2 Methods of Respiratory Muscle Training

The respiratory muscles consist of the expiratory muscles (abdominal muscles and internal intercostal muscles) and inspiratory muscles (diaphragm and external intercostal muscles), which, in conjunction with other auxiliary muscles, support the body's respiratory movements^[31]. Respiratory muscle training can be classified into four types based on the type of respiratory muscle: expiratory muscle training, inspiratory muscle training, combined respiratory muscle training, and auxiliary muscle group training methods^[32-34]. These training methods, through active breathing exercises or passive movements with the assistance of breathing training devices, improve the strength of the body's respiratory muscles, relieving the effort of breathing and providing corresponding improvements in the body's respiratory muscle function, lung function, maximum expiratory pressure, maximum inspiratory pressure, etc.

Traditional respiratory muscle training methods include diaphragmatic breathing, pursed-lip breathing, deep breathing, coughing training, etc^[35,36]. However, due to the slow effectiveness, tediousness of the training movements, and difficulty for patients to persist with traditional respiratory muscle training methods, they are less commonly used nowadays. More recent respiratory muscle training methods are preferred, including diaphragmatic training, threshold pressure load training, and high-intensity interval respiratory muscle training. Studies have proven that stroke patients can achieve the best training results if they undergo the above respiratory muscle training within three months after onset^[37].

2.3 The Physiological Mechanism of Respiratory Muscles and Swallowing Movements

Respiratory and swallowing movements are controlled by the same higher central nervous system located in the medulla oblongata^[38], closely coordinating during the oral and pharyngeal stages of swallowing. At the moment of swallowing, the respiratory muscles actively control the body to pause breathing briefly; after the swallowing action is completed at the end of inspiration, the action of

exhaling resumes. After a stroke, the central nervous system that regulates respiratory movements is damaged, affecting the respiratory muscles by decreasing muscle strength, weakening breathing capacity, reducing lung compliance, and restricting thoracic movement, ultimately leading to abnormal respiratory function^[39,40]. This disrupts the coordinated action between breathing and swallowing movements, hindering the normal swallowing process^[41]. Besides being governed by the same type of nerves, the processes of breathing and swallowing are also affected by the involvement of the same organs. The larynx, which is involved in the body's breathing, swallowing, and speaking functions^[42], is a very important respiratory organ. Studies have shown^[43] that the physiological functions and structure of the larynx closely affect swallowing function. Post-stroke patients with brain nerve damage exhibit abnormal laryngeal reflexes, limited pharyngeal muscle activity, slow laryngeal descent, and obstructed laryngeal elevation, leading to delayed or absent swallowing reflexes and thereby preventing the body from completing the entire set of swallowing actions smoothly. Zhou Li et al^[44] have proven that timely and effective respiratory muscle training can increase the range of laryngeal elevation, regulating and improving the coordination between swallowing-related muscles and respiratory muscles, thus improving swallowing function.

3. The Value of Respiratory Muscle Training in Improving Post-Stroke Swallowing Disorders

The role of respiratory muscle training is primarily manifested in improving respiratory difficulties, swallowing dysfunctions, balance disorders, etc., in post-stroke patients, enhancing the ability to cough effectively, reducing the risk of aspiration, and decreasing the total duration of hospital stay post-stroke. Park et al^[45] found that after respiratory muscle training, the muscles of the mouth and pharyngeal palate could be activated, playing a significant role in the rehabilitation of swallowing disorders. When the respiratory system functions normally, powerful respiratory muscle movements can reduce the occurrence of swallowing anomalies. Expiratory muscle training can effectively enhance respiratory muscle strength, improve respiratory muscle endurance, and alleviate the effort of breathing. Studies by Chen Hangyan et al^[46] have shown that expiratory muscle training not only enhances respiratory muscle strength but also correspondingly increases the strength of the geniohyoid muscle, having a certain effect in treating swallowing difficulties. Tian Ye et al^[47] conducted respiratory muscle training combined with electromyographic biofeedback training on post-stroke patients with concurrent swallowing disorders and found that respiratory muscle training increased respiratory muscle strength, the elevating range of the hyoid-laryngeal complex, enhanced the body's ability to clear airway foreign objects, and improved the coordination between swallowing and breathing, resulting in significant recovery of swallowing function in post-stroke patients.

The above research indicates that after the functions of the respiratory and swallowing muscle groups are positively activated, the chances of aspiration and coughing during the process of eating or drinking are reduced. Utilizing respiratory muscle training to improve the swallowing function of stroke patients is an effective and feasible approach. Moreover, respiratory muscle training has the advantages of being simple, easy to operate, safe, and practicable daily, suitable for the majority of post-stroke patients with swallowing disorders.

4. Summary

Swallowing disorders often occur post-stroke due to damage to multiple neurological functions and the body's physiological structures, causing patients to experience coughing, aspiration, aspiration pneumonia, etc. These disorders not only present significant physiological challenges to stroke patients but also subject them to complex psychological barriers, severely reducing their quality of life and even endangering their lifespan. Through analyzing the status and feasibility of research on regulating swallowing function through respiratory muscle training, it has been found

that respiratory muscle training has the potential to improve swallowing function, lung function, and quality of life for stroke patients. Considering the applicability and effectiveness of respiratory muscle training programs, it can provide a scientifically viable rehabilitation method for patients with post-stroke swallowing functional disorders.

References

- [1] Bo Chen, Zhaoxiang Meng, Min Su, et al. Progress in the application of mirror therapy in the early rehabilitation of patients with hemiplegia after stroke [J]. *Chinese Journal of Physical Medicine and Rehabilitation*, 2020, 42(1): 90-94.
- [2] Jiamin Lu, Sinian Jian, Yihao Chen, et al. Study on the characteristics of resting-state brain network of post-stroke cognitive impairment beneficiaries by functional near-infrared spectroscopy[J]. *China Rehabilitation Theory and Practice*, 2022(4): 447-452.
- [3] Longde Wang, Bin Peng, Hongqi Zhang, Yilong Wang, Ming Liu, Chunlei Shan, Lei Cao, Lingxiao Wang, Wei Xie, Peijian Wang, Lin Ma. Summary of "China Stroke Prevention and Treatment Report 2020"[J]. *Journal of Chinese Cerebrovascular Diseases*, 2022, 19(02): 136-144.
- [4] Eltringham SA, Kilner K, Gee M, et al. Factors Associated with Risk of Stroke-Associated Pneumonia in Patients with Dysphagia: A Systematic Review [J]. *Dysphagia*, 2020, 35(5): 735-744.
- [5] Yuqi Chai, Lei Teng, Yaojie Xin. The origin and verification of the anatomical name "epiglottis"[J]. *Basic Medical Journal of Chinese Traditional Medicine*, 2020, 26(11): 1638-1640.
- [6] Lee Y, Kim G, Wang S, et al. Acoustic Characteristics in Epiglottic Cyst[J]. *J Voice*, 2019, 33(4): 497-500.
- [7] Meiting Yu, Guodong Feng, Zhiqiang Gao. Application of fluorescence molecular imaging technology in head and neck tumor surgery[J]. *Chinese Journal of Otorhinolaryngology Head and Neck Surgery*, 2021, 56(2): 176-181.
- [8] Liqin Dong. Research progress on PD-1/PDL1 signaling pathway and its related immunotherapy in the treatment of head and neck tumors[J]. *Chongqing Medicine*, 2021, 50(3): 524-528.
- [9] Zhenya Li, Jie Sun, Guoqing Shao, et al. Study on the correlation between leakage aspiration and hyoid-laryngeal complex in patients with simple pharyngeal phase dysphagia after stroke[J]. *Chinese Journal of Rehabilitation Medicine*, 2022, 37(7): 964-967.
- [10] Weiwei Wang. Observation on the efficacy of enhanced respiratory control training in the treatment of post-stroke dysphagia [J]. *Zhejiang Journal of Integrated Traditional Chinese and Western Medicine*, 2018, 28(12): 1009-1011.
- [11] Jie Wang. The physiological mechanism of swallowing and post-stroke dysphagia[J]. *Chinese Journal of Stroke*, 2007, 10(03): 220-225.
- [12] Jinding Wang, Lijun Xu. Research progress on the pathophysiological mechanism of post-stroke dysphagia[J]. *Chinese Journal of Rehabilitation Medicine*, 2008, 23(7): 666-668.
- [13] Expert Consensus Group on Dietary Nutrition Management for Dysphagia in China, Expert Consensus on Dietary Nutrition Management for Dysphagia in China (2019 Edition)[J]. *Chinese Journal of Physical Medicine and Rehabilitation*, 2019, 41(12): 881-888.
- [14] Zulin Dou. *Assessment and Treatment of Dysphagia (2nd Edition with Added Value)[M]*. Beijing: People's Medical Publishing House, 2017:1.
- [15] Hägglund P, Koistinen S, Olai L, et al. Older people with swallowing dysfunction and poor oral health are at greater risk of early death[J]. *Community Dent Oral Epidemiol*, 2019, 47(6): 494-501.
- [16] Meng Cao, Xuemei Song, Li Liang, et al. Incidence and influencing factors of dysphagia after acute ischemic stroke [J]. *Journal of Nursing Science*, 2021, 36(2): 24-27.
- [17] Xiangrong Wu, Qiurong Dai, Xia Sun. The effect of acupuncture combined with neuromuscular electrical stimulation and catheter balloon dilatation on the mobility of the hyoid-laryngeal complex and nutritional status of patients with post-stroke dysphagia[J]. *Journal of Integrated Traditional Chinese and Western Medicine on Cardio-Cerebrovascular Disease*, 2023, 21(1): 157-160.
- [18] Hua Qin, Yafen Li. Logistic regression analysis of the incidence and influencing factors of multidrug-resistant respiratory tract infections in stroke patients[J]. *Chinese Journal of Health Inspection*, 2023, 33(02): 232-235+257.
- [19] Ching Wo Tung. Clinical observation of the efficacy of electroacupuncture with different waveforms in treating dysphagia after stroke[D]. *Guangzhou University of Chinese Medicine*, 2019. DOI: 10.27044/d.cnki.ggzcu.2019.000045.
- [20] Chuan Yu. Discussion on the selection of acupoints for acupuncture treatment of dysphagia after stroke[J]. *Journal of External Therapy of Traditional Chinese Medicine*, 2022, 31(01): 116-118.
- [21] Ting Cheng, Wenjie Hao, Xiang Li, Wangsheng He, Taohua Wei, Wenming Yang. Clinical observation of electrical stimulation combined with swallowing function training in the treatment of dysphagia in patients with hepatolenticular degeneration [J]. *Chinese Rehabilitation*, 2022, 37(08): 451-455.
- [22] Jiaqi Fan, Lijuan Chang. Research progress on rehabilitation nursing of swallowing disorders in patients with Parkinson's disease [J]. *Journal of Nursing Education*, 2023, 38(03): 229-232.

- [23] Jiamin Gao, Yanneng Huang, Yaqing Xie, Zhongnan Mao. Research progress on the clinical efficacy of electroacupuncture combined with rehabilitation training in the treatment of pharyngeal phase dysphagia after ischemic stroke [J]. *Clinical Research in Traditional Chinese Medicine*, 2021, 13(36): 52-54.
- [24] Chan Cai, Defang Cai. Research progress on screening and rehabilitation nursing for patients with post-stroke dysphagia [J]. *Chinese Journal of Geriatric Care Medicine*, 2023, 21(01): 122-125.
- [25] Jiawen Shen. Clinical study on the evaluation of pharyngeal phase swallowing kinematics characteristics of stroke patients by ultrasonography[D]. Shaoxing University, 2022. DOI: 10.27860/d.cnki.gsxwl.2022.000086.
- [26] Rubesin SE. Oral and pharyngeal dysphagia [J]. *Gastroenterol Clin North Am*, 1995, 24: 331-352.
- [27] Jing Zhang. The relationship between stroke injury location and difficulty in swallowing[J]. *Chinese Journal of Stroke*, 2007, 3: 214-219.
- [28] Mengxiong Zhao. Characteristics of dysphagia in patients with cerebral infarction and the influence of acupuncture comprehensive therapy on prognosis[D]. Tianjin University of Traditional Chinese Medicine, 2020. DOI: 10.27368/d.cnki.gzzy. 2020.000037.
- [29] Xiran Yin. Characteristics of dysphagia in acute ischemic stroke and analysis of related influencing factors[D]. Zhengzhou University, 2021. DOI: 10.27466/d.cnki.gzzdu.2021.000548.
- [30] Liaw M Y, Hsu C H, Leong C P, et al. Respiratory muscle training in stroke patients with respiratory muscle weakness, dysphagia, and dysarthria: a prospective randomized trial [J]. *Medicine (Baltimore)*, 2020, 99(10): e19337.
- [31] Danian Zhu, Tinghuai Wang. Physiology[M]. 9th Edition. Beijing: People's Health Publishing, 2018: 168.
- [32] Shihao Wang, Zhiwan Wang. Research progress on rehabilitation exercises for respiratory muscle fatigue in chronic obstructive pulmonary disease[J]. *Nursing Research*, 2021, 35(20): 3641-3646.
- [33] Haijin Lv, Haiqing Zheng, Jianrong Liu, Qing Cai, Yujie Ren, Huimin Yi, Yang Yang, Xiquan Hu, Guihua Chen. Expert consensus on perioperative rehabilitation assessment and intervention for liver transplantation in patients with acute-on-chronic liver failure[J]. *Organ Transplantation*, 2022, 13(05): 543-554.
- [34] Mingyue Wang, Caiqin Wu, Jieting Jiang, Chenfei Weng, Kunpeng Li. Clinical characteristics and nursing progress of respiratory muscle injury in stroke patients[J]. *Nursing and Rehabilitation*, 2022, 21(08): 89-91+95.
- [35] Yunqi Chu, Huijin Guo, Yijing Liu, Jing Shi, Kaihua Lu. Research progress on exercise intervention in the prognosis of lung cancer surgery patients[J]. *Chinese Journal of Surgical Oncology*, 2020, 12(02): 166-169.
- [36] Lanying He, Hong Yu. Study on the application of active respiratory cycle training in patients undergoing esophageal cancer resection[J]. *Contemporary Nurse (Second Half of the Month)*, 2022, 29(08): 73-75.
- [37] Fabero-Garrido R, Del Corral T, Angulo-D úz-Parreño S, et al. Respiratory muscle training improves exercise tolerance and respiratory muscle function/structure post-stroke at short term: A systematic review and meta-analysis.[J]. *Ann Phys Rehabil Med*. 2022, 65(5): 101596.
- [38] Bangliang Liu, Meilan Zhu, Huiyu Liu, et al. The interaction between breathing and swallowing and its application [J]. *China Rehabilitation Theory and Practice*. 2018. 24(10): 1165-1168.
- [39] Menezes KK, Nascimento LR, Avelino PR, et al. Efficacy of Interventions to Improve Respiratory Function After Stroke. [J]. *Respir Care*. 2018, 63(7): 920-933.
- [40] Pozuelo-Carrascosa DP, Carmona-Torres JM, Laredo-Aguilera JA, et al. Effectiveness of Respiratory Muscle Training for Pulmonary Function and Walking Ability in Patients with Stroke: A Systematic Review with Meta-Analysis.[J]. *Int J Environ Res Public Health*. 2020, 17(15): 5356.
- [41] Choi Y M, Park G Y, Yoo Y, et al. Reduced Diaphragm Excursion During Reflexive Citric Acid Cough Test in Subjects With Subacute Stroke.[J]. *Respir Care*. 2017, 62(12): 1571-1581.
- [42] Lei Ping, Xiaoling Liu, Jian Liu, et al. Research progress on the application of percutaneous laryngeal ultrasound in evaluating vocal cord function[J]. *Practical Medical Imaging Journal*, 2020, 21(4): 399-400.
- [43] Yupei Che. Comparison between cordectomy with laryngeal fissure and partial laryngectomy in the treatment of laryngeal cancer [J]. *Jilin Medicine*, 2023, 44(02): 327-330.
- [44] Li Zhou, Mingxing Zhang, Yihua Shi, et al. The effect of respiratory muscle training combined with electromyographic biofeedback training on postoperative swallowing function and aspiration pneumonia in patients with laryngeal cancer [J]. *Chinese Medical Sciences*, 2018, 8(16): 7-10+52.
- [45] Park JS, Oh DH, Chang MY, Kim KM. Effects of expiratory muscle strength training on oropharyngeal dysphagia in subacute stroke patients: a randomised controlled trial. [J]. *J Oral Rehabil*. 2016, 43(5): 364-372.
- [46] Hangyan Chen, Meirong Zhong, Xiaoyuan Huang, et al. Research progress on the compliance of cardiac rehabilitation in patients with coronary heart disease[J]. *Practice and Research of Nursing*, 2022. 19(8): 1157-1161.
- [47] Tian Ye, Kehui Hu, Huan Yang, et al. The effect of respiratory muscle training combined with electromyographic biofeedback training on swallowing function and aspiration pneumonia after stroke[J]. *Journal of Rehabilitation*, 2018, 28(01): 41-44.