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Original Article

The value of inspiratory muscle training on poststroke sarcopenia and its effect on rehabilitation outcomes: A randomized controlled trial

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ABSTRACT

Objectives: The purpose of the study was to validate the effectiveness of inspiratory muscle training (IMT) in preventing poststroke sarcopenia and to examine the impact of IMT on the prognosis for stroke recovery.

Patients and methods: In the randomized controlled trial, 367 patients with a first stroke event between December 2021 and May 2023 were randomly allocated to an experimental group and a control group. Of the patients, 329 (179 males, 150 females; mean age: 61.0±8.7 years; range, 35 to 78 years) completed the experiment and were included in the analyses (experimental group, n=164; control group, n=165). Both groups received conventional neurological rehabilitation treatment, and the experimental group also received IMT. The incidence of poststroke sarcopenia and pneumonia during four weeks of treatment were examined and compared. Additionally, an analysis was conducted on the variations between the two groups in maximal inspiratory pressure (MIP), modified Rankin scale (mRS), trunk impact scale (TIS), and modified Barthel index (MBI).

Results: Following four weeks of therapy, the experimental group experienced a reduced incidence of poststroke sarcopenia (p=0.004) and pneumonia (p=0.017) than the control group. The trial group performed better than the control group in MBI (p=0.002), TIS (p<0.001), MIP (p<0.001), and mRS (p=0.011) scores after intervention.

Conclusion: In conclusion, the findings demonstrate that early IMT can significantly lower the risk of poststroke sarcopenia and pneumonia while also improving the prognosis for stroke patients' recovery.

Keywords: Activities of daily living, inspiratory muscle, sarcopenia stroke.

Stroke is one of the significant diseases threatening human health, characterized by high incidence, high disability rate, and high mortality rate. After a stroke, the skeletal muscles are frequently severely damaged. Roughly two-thirds of stroke patients suffer varying levels of motor, cognitive, emotional, and social dysfunction, severely affecting their quality of life. Additionally, stroke negatively affects the efficiency of coughing and respiratory muscle function,[1] increasing the likelihood of aspiration and pneumonia and resulting in longer hospitalization, higher mortality, and worse functional outcomes.

Age is a prevalent factor in primary sarcopenia, a gradual, systemic skeletal muscle disease characterized by decreased skeletal muscle mass, inadequate muscle strength, and physical dysfunction. Secondary sarcopenia, on the other hand, is a condition that can develop as a result of certain systemic disorders and is unrelated to aging. Poststroke sarcopenia is the term used to describe the secondary sarcopenia that follows a stroke. Earlier studies have shown a 50% prevalence of poststroke sarcopenia in the first month and 34% after six months,[2] with an average prevalence over the first six months of 46.7±0.49%.[3] Its occurrence is related to factors such as poststroke dyskinesia, eating disorders, inflammation, sympathetic activation, denervation, and neuropathic pain.[4] After a stroke, sarcopenia can exacerbate the impairment that stroke victims already face and have an impact on their

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capacity to walk independently, maintain balance, and carry out everyday tasks. Improvements in poststroke sarcopenia can minimize hospitalization time and improve the patient's capacity to carry out routine activities.[5]

The stroke mostly impacts the contralateral corticospinal system, resulting in diminished strength in the contralateral limbs and trunk muscles, which includes the respiratory muscles. Studies have shown average reductions of 21.4±0.5% in the hemiplegic diaphragmatic activity in stroke patients compared to that in normal people,[6] and the baseline average inspiratory muscle strength of subacute stroke patients was found to be only 46±7 cmH_2O.[7] Research has demonstrated a significant correlation between the strength of the respiration muscles and the strength of the limb muscles.[8] Indicators of sarcopenia, such as limb muscle strength and the skeletal muscle index, are positively associated with the respiratory muscle strength of healthy individuals, particularly the inspiratory muscle strength, and negatively correlated with the occurrence of sarcopenia. Reductions of 1 cmH_2O in maximal inspiratory pressure (MIP) and maximal expiratory pressure can increase the probability of sarcopenia by 8 and 7%, respectively.[9] Studies have shown that sarcopenia, a complication of chronic obstructive pulmonary disease (COPD), can be mitigated by 28% with the implementation of inspiratory muscle training (IMT).[10] Therefore, IMT may be useful in preventing poststroke sarcopenia.

However, little is known about how IMT affects patients with stroke. The objective of this study was to investigate the potential of IMT in decreasing the occurrence of poststroke sarcopenia. Additionally, the study aimed to analyze the impact of IMT on the rehabilitation prognosis of stroke patients, enhance the early rehabilitation program for stroke, improve the efficacy of rehabilitation, and minimize poststroke disability.

PATIENTS AND METHODS

The study design employed was a prospective, single-blind, randomized controlled experiment. The patients were assigned to the two groups using a stratified random method based on their sex and age, with a cutoff of 65 years. A total of 700 patients who had suffered from strokes were screened from the Peoples Hospital of Deyang City, Department of Rehabilitation Medicine, Department of Neurology, and Department of Neurosurgery between December 2021 and May 2023. A written informed consent was obtained from each patient. The study protocol was approved by the Peoples Hospital of Deyang City Ethics Committee (date: 15.11.2021, no: 2021-04-148-K01). The study was conducted in accordance with the principles of the Declaration of Helsinki. The patients were required to fulfill the subsequent inclusion criteria: *(i)* first unilateral stroke meeting the diagnostic criteria for stroke established at the Fourth National Academic Conference on Cerebrovascular Diseases in 1995; *(ii)* a course of disease lasting ≤4 weeks; *(iii)* A MIP <60 cmH_2O; *(iv)* a body mass index (BMI) >18.5 kg/m^2; *(v)* stable vital signs with no tracheal intubation and tracheotomy; *(vi)* the ability to participate fully in the training without obvious cognitive impairment. Patients were excluded on the following grounds: *(i)* age <18 years; *(ii)* the presence of prestroke sarcopenia (SARC-F [strength, assistance in walking, rising from a chair, climbing stairs, and falls] score ≥4, with calf circumferences below the threshold of <34 cm for males and <33 cm for females); *(iii)* the inability to complete IMT due to significant facial paralysis or additional structural issues in the oropharynx. After applying the exclusion criteria, 367 patients were included in the study. The patients were randomly allocated to the experimental group (n=184) and the control group (n=183). During the study, 38 patients withdrew from the study due to personal reasons (20 in the experimental group and 18 in the control group). Therefore, a total of 329 patients (179 males, 150 females; mean age: 61.0±8.7 years; range, 35 to 78 years) completed the experiment and were subsequently included in the analysis (Figure 1).

The control group received traditional neurorehabilitation treatment. This included comprehensive training for hemiplegic limbs (45 min/session, once daily), power bicycle training (30 min/session, twice daily), hand function training (30 min/session, twice daily), and neuromuscular electrical stimulation therapy (45 min/session, once daily). The training sessions were held on a frequency of five days per week, spanning four weeks.

The experimental group received additional IMT in addition to the conventional neurorehabilitation treatment given to the control group. To measure the MIP before the first IMT, the patients used a respiratory endurance trainer (Model S2; Xeek Medical Appliance Company Limited, Xiamen, China), with the threshold resistance adjusted to 3 cmH_2O. While seated comfortably and slightly leaning forward, the patient performed calm abdominal breathing until breathing stabilized. The MIP was measured at the

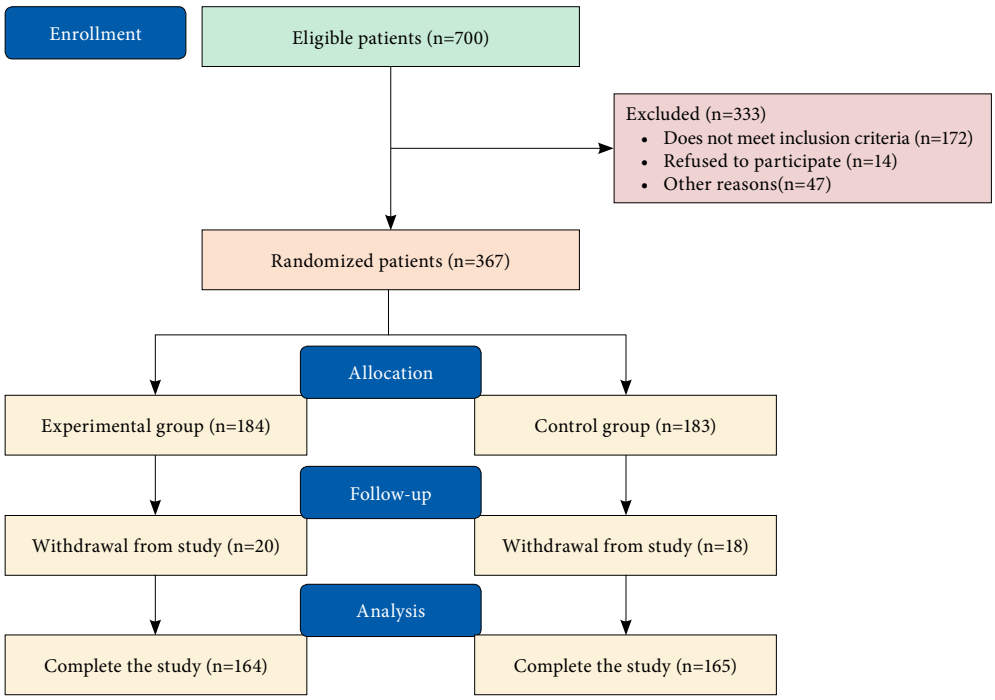

Figure 1. Flow chart of the study protocol.

end of expiration by the patient forcefully inhaling and holding their breath for 2 to 3 sec. The measurement was repeated three times, with the maximum value selected as the MIP. The MIP was reevaluated every two weeks.

When the patients performed IMT, the resistance was adjusted to 30% of the latest MIP value. The patients took a comfortable seated position with the body slightly inclined forward, and they calmly performed abdominal breathing until the breathing was stable. At the end of exhalation, the patients inhaled forcefully to the maximum lung capacity and then exhaled slowly. This was performed 30 times per group, two groups per day. The patients engaged in rest periods after completing three to five repetitions, adjusting the duration based on their level of fatigue. The duration of the training program was four weeks, with sessions held five days a week. Inspiratory muscle training can be conducted either autonomously or under supervision. The training was stopped if the patient encountered symptoms such as dizziness, headache, difficulty breathing, or a reduction of above 4% in oxygen saturation.

Baseline clinical data, such as sex, age, BMI, comorbidities, National Institute of Health stroke scale (NIHSS),[11] and Mini-Mental State Examination (MMSE)[12] were evaluated before training. Following a four-week training period, a medical professional or physical therapist assessed the occurrence of poststroke sarcopenia and pneumonia in both groups. The MIP, activities of daily living, social regression, and balancing functions were examined at the beginning and end of the therapies in both groups. The evaluators were blinded to the study purpose and the subject distribution.

As per the 2019 Asian Consensus on the Diagnosis and Treatment of Sarcopenia,[13] the diagnosis of primary sarcopenia requires a decline in both muscle strength and skeletal muscle mass.[13] Nevertheless, numerous studies have suggested the use of calf circumference as an alternate measure to assess skeletal muscle mass in poststroke patients.[14-17] Thus, in our study, we utilized grip strength and calf circumference on the nonhemiplegic side as diagnostic criteria for poststroke sarcopenia. Sarcopenia was diagnosed when grip strength was <28 kg for males and <18 kg for females, and calf circumference was <34 cm for males and <33 cm for females.[13]

To assess grip strength, the patient held a spring-type grip strength device in the sitting position or the auxiliary sitting position and extended their elbow for two equal-length contractions with

maximum force, with a 1-min rest after each. The maximum reading represented the grip strength.

To measure calf circumference, the patient lay in the supine position in the morning, with the knee joint on the nonhemiplegic side flexed at 90° while the ankle joint was relaxed. The maximum calf circumference was measured using a nonelastic band.

The occurrence of pneumonia in both groups was evaluated during the training and quantified as the percentage ratio of the number of pneumonia cases to the total number of patients in each group.

The MIP measurement was repeated three times to obtain the optimal value. The normal MIP values are 120±37 cmH_2O for males and 84±30 cmH_2O for females.[18] The intervention part included a description of the MIP measuring method.

The modified Barthel Index (MBI), which consists of 10 items (eating, dressing, defecating, urinating, toileting, walking, ascending stairs, transferring, modifying, and bathing), was used to assess activities of daily living.[19] The maximum score is 100, and patients with a score >60 can mostly take care of themselves. Scores between 40 and 60 indicate moderate disability, dysfunction, and a requirement for help, while 20 to 40 points indicate severe disability with significant dependence. Patients with a score <20 are completely disabled and dependent on others for daily living.

Social regression capability was assessed with the modified Rankin scale (mRs).[20] The criteria were as follows: 0= completely asymptomatic; 1= the ability to perform all everyday tasks despite the presence of symptoms but without evident malfunction; 2= a mild impairment that prevents them from doing all preillness activities but allows them to manage their everyday tasks independently; 3= a mild disability that needs assistance yet allows for independent walking; 4= a moderate to severe handicap characterized by an inability to walk on one's own and a need for daily assistance from others; 5= severe disability, bedridden, complete dependence on others for daily living. Of a total score of 0 to 5 points, scores ≤3 indicated good function with the patient capable of walking independently, while scores >3 indicated that the patient had poor function and needed help in daily life.

The trunk impairment scale (TIS) is used for evaluating trunk balance in nervous system diseases and consists of 17 items.[21] These include static sitting balance (three items, 7 points in total), dynamic sitting balance (10 items, 10 points in total), and trunk coordination (four items, 6 points in total). The overall score ranges between 0 and 23, with higher scores indicating better balance. The validity and reliability of the scale have been assessed in stroke patients.[21]

Statistical analysis

To ascertain the necessary number of participants, we determined the sample size by taking into account the findings of earlier research using the PASS software version 11 (NCSS, LLC, Kaysville, Utah, USA). The mean prevalence of sarcopenia within six months following a stroke was determined to be 46.7±0.49%.[22] It would take 165 patients in each group, assuming a 15% clinical difference, to test the difference between the two groups at 80% power and 5% significance (two-tailed). Accounting for a 10% loss to follow-up, each group required a minimum of 181 subjects. Therefore, 362 subjects in total were needed for the two groups.

The statistical analyses were conducted using IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was employed to assess the normal distribution of the data. Descriptive data were expressed in percentages, mean ± standard deviation (SD), and median (min-max). When the data met the criteria of normality and homoscedasticity, independent t-tests were employed to compare different groups, whereas paired t-tests were utilized to compare within-group measurements before and after treatment. The Mann-Whitney U test was employed to compare nonnormality between groups, whereas the Wilcoxon signed-rank sum test was utilized to compare within-group differences. The incidence of sarcopenia and pneumonia between the two groups was compared using the chi-square test. Two-sided tests were used for statistical analysis, and a p-value <0.05 indicated statistical significance.

RESULTS

There were no significant variations in the baseline clinical data, including NIHSS, MMSE, mRS, MBI, TIS, MIP, and calf circumference, between the two groups at the beginning of the study (Table 1). Therefore, the groups were considered to be similar. No adverse effects were observed during or after therapy.

After four weeks of intervention, the incidence of poststroke sarcopenia in the experimental group was 22%, which was significantly lower than the 36.4% observed in the control group (p=0.004, Figure 2). Over four weeks, the experimental group developed a

TABLE 1
Baseline demographics of both groups

	Experimental group (n=164)					Control group (n=165)					
	n	%	Mean±SD	Median	Min-Max	n	%	Mean±SD	Median	Min-Max	*p*
Age (year)			61.3±8.8	64	35-75			60.6±8.6	62	36-78	0.482*
Sex											0.695 ‡
Male	91	50.8				88	49.2				
Female	73	48.7				77	51.3				
BMI (kg/m^2)			22.46±2.18	22.5	18-28			22.6±2.13	22.67	18.36-28.3	0.540*
Etiology											0.204‡
Ischemia	79	48.2				68	41.2				
Hemorrhage	85	51.8				97	58.5				
Hemiplegia											0.202‡
Right	75	45.7				64	38.8				
Left	89	54.3				101	61.2				
Dominant hand											
Right	180	-				180	-				
Left	0	-				0	-				
Dysphagia	120	73.2				125	75.8				0.591‡
Complication	156	95.1				162	98.2				0.123‡
Hypertension	99	60.4				107	64.8				0.401‡
Diabetes	55	33.5				58	35.2				0.758‡
Hyperlipemia	20	12.2				16	9.7				0.468‡
CHD	22	13.4				26	15.8				0.547‡
Arrhythmia	17	10.4				12	7.3				0.322‡
Osteoporosis	5	3				5	3				0.992‡
Albumin			37.49±4.68	38.95	21-48.6			36.56±4.89	37	25-49	0.360#
Prealbumin			198±41.74	200	101-272			193.6±41.81	200	108-288	0.306#
CRP			24.67±32.52	10.59	1-144			24.04±35.05	11	0.5-161.35	0.943#
Hemoglobin			130.36±16.14					128.2±15.02			0.210*
RBC			4.31±0.56					4.29±0.56			0.825*
NIHSS			13.39±6.01	15	3-27			12.89±6.05	14	3-26	0.413#
mRS			3.48±0.63	4	2-4			3.44±0.61	3	2-4	0.395#
MBI			44.06±11.64	43.5	22-68			44.21±10.99	45	23-70	0.855#
MMSE			24.13±2.29	24	20-29			24.1±2.2	24	21-29	0.888#
TIS			11.32±2.49	11	5-18			11.55±2.44	12	6-20	0.325#
MIP			31.36±8.95					30.87±9.01			0.623*
CC			32±4.34	33	19-39			31.91±4.17	33	18-37	0.798#

SD: Standard deviation; BMI: Body mass index; CHD: Coronary heart disease; CRP: C-reactive protein; RBC: Red blood count; NIHSS: National Institute of Health stroke scale; mRS: Modified Rankin scale; MBI: Modified Barthel index; MMSE: Mini-Mental State Examination; TIS: Trunk impact scale; MIP: Maximal inspiratory pressure; CC: Calf circumference; * Analyzed by independent t-test; ‡ Analyzed by the chi-square test; # Analyzed by the Mann-Whitney U test.

pneumonia incidence of 7.3%, which was significantly lower than the rate observed in the control group (15.8%; p=0.017, Figure 3).

Following the completion of the treatment, both groups exhibited elevated MIP. However, the experimental group demonstrated significantly higher MIP compared to the control group (p<0.001). The difference in the MIP before and after the intervention also differed significantly between the two groups (p<0.001, Table 2).

Following the intervention, the MBI showed an increase in both groups, with the experimental group demonstrating considerably higher scores compared to the control group (p=0.01). The difference in the

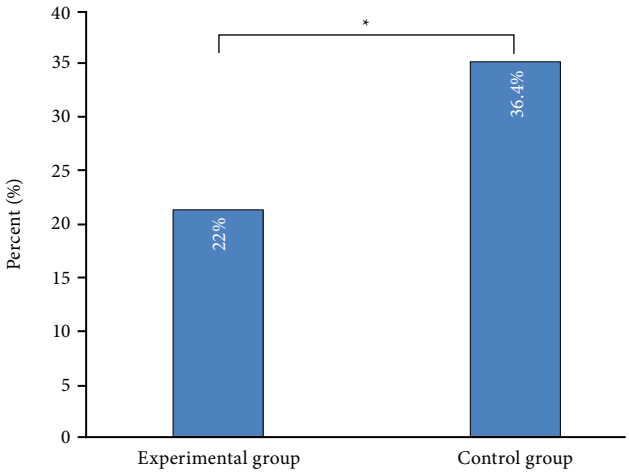

Figure 2. Comparison of incidence of poststroke sarcopenia.
* The asteriks indicate significance intergroup comparisons (p<0.001).

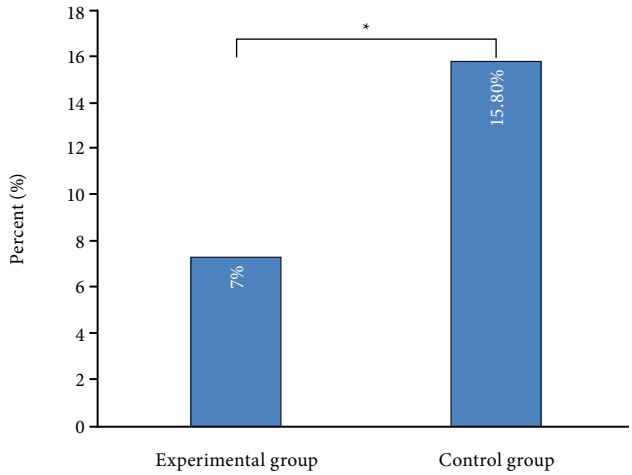

Figure 3. Comparison of pneumonia incidence.
* The asteriks indicate significance intergroup comparisons (p<0.001).

MBI before and after the intervention also differed significantly between the two groups (p=0.002, Table 2).

After the intervention, both groups exhibited decreased mRS ratings compared to before the intervention. Additionally, the experimental group displayed lower mRS values in comparison to the control group (p=0.011). The differences in the mRS scores also differed significantly before and after the intervention between the two groups (p=0.001, Table 2).

TABLE 2
Intra group and inter group comparisons of two groups secondary outcomes

	Experimental group			Control group			
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	*p*
MBI (T0)	44.06±11.64	43.5	22-68	44.21±10.99	45	23-70	0.855
MBI (T1)	65.27±11.31			62.33±9.28			0.010*
MBI (T1-T0)	21.18±9.77			18.15±8.03			0.002*
p value		<0.001**			<0.001**		
TIS (T0)	11.32±2.49	11	5-18	11.55±2.44	12	6-20	0.325
TIS (T1)	17.59±5.06			15.08±4.8			<0.001*
TIS (T1-T0)	6.29±2.53	6	1-13	3.54±2.4	4	-2-9	<0.001#
p value		<0.001†			<0.001†		
MIP (T0)	31.36±8.95			30.87±9.01			0.623
MIP (T1)	47.99±9.21	46.5	29-70	43.97±9.14	43	26-68	<0.001#
MIP (T1-T0)	16.63±8.57	16	1-42	13.09±9.2	12	-10-39	<0.001#
p value		<0.001†			<0.001†		
mRS (T0)	3.48±0.63	4	2-4	3.44±0.61	3	2-4	0.395
mRS (T1)	2.53±0.79	3	1-4	2.72±0.63	3	1-4	0.011#
mRS (T1-T0)	0.95±0.65	1	-1-3	0.72±0.56	1	-1-3	0.001#
p value		<0.001†			<0.001†		

SD: Standard deviation; MBI: Modified Barthel index; TIS: Trunk impact scale; MIP: Maximal inspiratory pressure; mRS: Modified Rankin scale; T0: Before intervention; T1: After four weeks of intervention; T1-T0: The difference between T1 and T0; * Analyzed by independent t-test; # Analyzed by Mann-Whitney U test; ** Analyzed by the paired t test; † Analyzed by the Wilcoxon signed-rank test.

After the intervention, it was observed that the TIS scores had increased in both groups. However, the patients in the experimental group had considerably higher scores compared to those in the control group ($p<0.001$). The difference in the TIS scores before and after the intervention exhibited an apparent difference between the two groups ($p<0.001$, Table 2).

DISCUSSION

Stroke can result in respiratory impairment, which significantly affects motor function. Research has indicated that reduced respiratory function is a primary factor contributing to nonvascular mortality following a stroke.[7] Respiratory training can improve motor abilities and reduce the likelihood of stroke-related complications and mortality.[7] However, respiratory training for stroke has not been widely used in China. The current study showed that the occurrence of poststroke sarcopenia and pneumonia was reduced in patients who underwent early IMT compared to the control group. In addition, the treated patients performed better than those in the control group in activities of daily living, social regression, balance functions, and inspiratory muscle strength. As a result, our study conclusively shows that IMT is a simple and efficient training technique that may contribute to reducing the occurrence of poststroke sarcopenia and promoting functional recovery after stroke.

Inspiratory muscle training and poststroke sarcopenia

Due to central factors, reduced activity, malnutrition, and other causes, stroke patients often experience a decline in respiratory muscle strength and the occurrence of poststroke sarcopenia. Studies have shown that inspiratory muscle strength is correlated with sarcopenia markers, such as grip strength and skeletal muscle index.[8] Lower inspiratory muscle strength is associated with an increased incidence of sarcopenia.[23] Jones et al.[10] found that the incidence of sarcopenia related to COPD can be reduced by 28% after IMT. This may be because respiratory training can mitigate the "blood steal" phenomena in the inspiratory muscles and reduce fatigue in the skeletal muscles in the limbs, thereby improving exercise tolerance and reducing the risk of sarcopenia. Currently, there is limited research on the prevention and treatment of poststroke sarcopenia through respiratory training. Our study investigated the impact of IMT on poststroke sarcopenia on the basis of the correlation between inspiratory muscle strength and grip strength. The study found that the incidence of sarcopenia was lower in the IMT group compared to the control group. It is speculated that IMT may contribute to the reduction of poststroke sarcopenia, laying the foundation for future research.

Inspiratory muscle training, MBI, and mRS

Dyskinesia is the primary abnormality observed following a stroke, which impairs patients' ability to do their regular tasks and elevates the likelihood of pneumonia. Recent studies have demonstrated that prestroke sarcopenia is a predictor of poor mRS in stroke patients three months after the stroke.[24] Additionally, poststroke sarcopenia is related to poor prognosis, specifically in the ability to perform daily activities, overall improvement, and the possibility of hospital discharge.[25] This study demonstrated that the experimental group exhibited better improvements in both social regression and the capacity to complete daily living activities compared to the control group. One possible explanation for this outcome is the reduced occurrence of poststroke sarcopenia. This is consistent with previous research.[5,26]

On the other hand, cardiopulmonary function may be affected after stroke, and it can remain reduced for several years.[27] Inspiratory muscle training can significantly enhance respiratory function, improve cardiopulmonary endurance, and decrease the occurrence of pneumonia following a stroke.[28,29] Respiratory muscle training involves long and repeated resistance training of the respiratory muscles, which helps to enhance respiratory endurance and enables patients to more efficiently utilize their respiratory muscles in daily life.[30] Prior research has demonstrated that IMT can effectively activate the diaphragm and sternocleidomastoid muscle while simultaneously decreasing sympathetic nervous activity. This training method also promotes a deep and slow breathing pattern in patients with COPD, which is beneficial to exercise.[31] Additionally, IMT has been found to enhance the inspiratory muscles strength in patients with various conditions, such as lung disease, asthma,[32] chronic heart failure, chronic kidney disease, and spinal cord injury,[33] and improve the dyspnea and quality of life in daily activities.

Inspiratory muscle training and balance

Our investigation revealed that the patients in the experimental group had a higher level of balance

function compared to those in the control group. Additionally, the incidence of sarcopenia was lower in the experimental group than in the control group. Research has demonstrated that sarcopenia adversely impacts balance, mobility, and overall function. Older individuals with sarcopenia are three times more prone to falling compared to those without sarcopenia.[34] Most stroke patients experience a reduction in respiratory muscle strength, which consequently impacts their trunk stability. Asymmetric movements of the trunk, in turn, may impact respiratory muscle function. Respiratory training has been shown to be effective as a type of trunk control training in patients with stroke, heart failure, and COPD.[35-36] The improvement in balance function induced by IMT might be attributed to two factors. First, the inspiratory muscles belong to the core muscle group, and their training helps enhance the thoracic movement of the trunk and the oxygen supply to the four limbs, thereby improving the trunk balance, transfer ability, and limbs' motor coordination. Second, IMT helps to prevent poststroke sarcopenia, consequently mitigating the decline in balance function and the occurrence of falls associated with poststroke sarcopenia. However, some studies reported that IMT had no obvious beneficial effect on the balance of stroke patients,[37,38] which might be related to bias induced by the small sample size.

Inspiratory muscle training and respiratory muscle strength

The median MIP of stroke patients is 42 cmH_2O (17-57),[7] which is lower than the threshold of 60 cmH_2O for inspiratory muscle weakness in patients with nervous system diseases.[39] The decrease in respiratory muscle strength is closely related to the reduced cardiopulmonary endurance in stroke patients who have approximately 40% lower motor capacity than sedentary individuals. The decline in MIP is closely linked to an increased risk of heart failure, myocardial infarction, cardiovascular death, and stroke.[40] In stroke patients, the respiratory function does not fully recover within a rehabilitation time of up to nine months if respiratory training is not provided.[41] The primary application of IMT is now focused on the pulmonary function rehabilitation of patients diagnosed with COPD, heart failure, stroke, and myasthenia gravis. Studies on IMT have demonstrated its ability to effectively enhance diaphragm thickness, MIP, and endurance of the inspiratory muscles in stroke patients. Additionally, IMT has been found to decrease the occurrence of pneumonia.[7,29,42] Our study affirmed previous research by demonstrating that, compared to the control group, the experimental group experienced significant improvement in inspiratory muscle strength after IMT, as well as a reduced incidence of pneumonia.

This study had a number of limitations. First, grip strength was not used as a diagnostic criterion for prestroke sarcopenia. This was because patients in the early phase of stroke are in a weakened condition, making it difficult to evaluate their grip strength adequately. Furthermore, the study's findings only indicated the disparity between the two groups following the implementation of the intervention. Hence, additional research is necessary to assess its enduring efficacy in rehabilitation.

In conclusion, the results of the present study revealed that implementing early IMT in neural rehabilitation for patients following their initial stroke can effectively decrease the occurrence of poststroke sarcopenia and pneumonia. Additionally, it can enhance inspiratory muscle strength, balancing function, and overall quality of daily living and social interactions. Early IMT not only improves respiratory muscle function but also provides stable trunk support for limb function recovery. This recovery process conforms to the neurophysiological development laws from the central area to the limbs. Based on our findings, we believe that incorporating IMT into regular stroke rehabilitation programs at an early stage can decrease the occurrence of poststroke sarcopenia and enhance functional recovery.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Contributed to the design of the study: Z.Q.P., S.C.L., W.Y.Z.; Has made contributions to conception and design of the study as well as being the main responsible in drafting the initial manuscript: Z.Q.P.; Has contributed with drafting the manuscript and revising it critical for important intellectual content: S.C.L., W.Y.Z.; Has contributed with the data collection, collation and data statistics: Z.Q.P., Z.W., G.H.; Made contributions to administer the intervention programme: Z.W.W., W.Y.Z.; Was responsible for the implementation of the rehabilitation program and data collection: W.L., C.T.T., M.Y.X. All authors read and approved the final manuscript.

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REFERENCES

1. Lasserson D, Mills K, Arunachalam R, Polkey M, Moxham J, Kalra L. Differences in motor activation of voluntary and reflex cough in humans. Thorax 2006;61:699-705. doi: 10.1136/thx.2005.057901.
2. Su Y, Yuki M, Otsuki M. Prevalence of stroke-related sarcopenia: A systematic review and meta-analysis. J Stroke Cerebrovasc Dis 2020;29:105092. doi: 10.1016/j.jstrokecerebrovasdis.2020.105092.
3. Yao R, Yao L, Rao A, Ou J, Wang W, Hou Q, et al. Prevalence and risk factors of stroke-related sarcopenia at the subacute stage: A case control study. Front Neurol 2022;13:899658. doi: 10.3389/fneur.2022.899658.
4. Li W, Yue T, Liu Y. New understanding of the pathogenesis and treatment of stroke-related sarcopenia. Biomed Pharmacother 2020;131:110721. doi: 10.1016/j.biopha.2020.110721.
5. Matsushita T, Nishioka S, Taguchi S, Yamanouchi A, Okazaki Y, Oishi K, et al. Effect of improvement in sarcopenia on functional and discharge outcomes in stroke rehabilitation patients. Nutrients 2021;13:2192. doi: 10.3390/nu13072192.
6. Park GY, Kim SR, Kim YW, Jo KW, Lee EJ, Kim YM, et al. Decreased diaphragm excursion in stroke patients with dysphagia as assessed by M-mode sonography. Arch Phys Med Rehabil 2015;96:114-21. doi: 10.1016/j.apmr.2014.08.019.
7. Menezes KK, Nascimento LR, Ada L, Polese JC, Avelino PR, Teixeira-Salmela LF. Respiratory muscle training increases respiratory muscle strength and reduces respiratory complications after stroke: A systematic review. J Physiother 2016;62:138-44. doi: 10.1016/j.jphys.2016.05.014.
8. Shin HI, Kim DK, Seo KM, Kang SH, Lee SY, Son S. Relation between respiratory muscle strength and skeletal muscle mass and hand grip strength in the healthy elderly. Ann Rehabil Med 2017;41:686-92. doi: 10.5535/arm.2017.41.4.686.
9. Pedreira RBS, Fernandes MH, Brito TA, Pinheiro PA, Coqueiro RDS, Carneiro JAO. Are maximum respiratory pressures predictors of sarcopenia in the elderly? J Bras Pneumol 2022;48:e20210335. doi: 10.36416/1806-3756/e20210335.
10. Jones SE, Maddocks M, Kon SS, Canavan JL, Nolan CM, Clark AL, et al. Sarcopenia in COPD: Prevalence, clinical correlates and response to pulmonary rehabilitation. Thorax 2015;70:213-8. doi: 10.1136/thoraxjnl-2014-206440.
11. Sato S, Toyoda K, Uehara T, Toratani N, Yokota C, Moriwaki H, et al. Baseline NIH Stroke Scale Score predicting outcome in anterior and posterior circulation strokes. Neurology 2008;70:2371-7. doi: 10.1212/01.wnl.0000304346.14354.0b.
12. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189-98. doi: 10.1016/0022-3956(75)90026-6.
13. Chen LK, Woo J, Assantachai P, Auyeung TW, Chou MY, Iijima K, et al. Asian working group for sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc 2020;21:300-7.e2. doi: 10.1016/j.jamda.2019.12.012.
14. Inoue T, Maeda K, Shimizu A, Nagano A, Ueshima J, Sato K, et al. Calf circumference value for sarcopenia screening among older adults with stroke. Arch Gerontol Geriatr 2021;93:104290. doi: 10.1016/j.archger.2020.104290.
15. Nishioka S, Yamanouchi A, Matsushita T, Nishioka E, Mori N, Taguchi S. Validity of calf circumference for estimating skeletal muscle mass for Asian patients after stroke. Nutrition 2021;82:111028. doi: 10.1016/j.nut.2020.111028.
16. Yao R, Yao L, Yuan C, Gao BL. Accuracy of calf circumference measurement, SARC-F questionnaire, and Ishii's score for screening stroke-related sarcopenia. Front Neurol 2022;13:880907. doi: 10.3389/fneur.2022.880907.
17. Kawakami R, Murakami H, Sanada K, Tanaka N, Sawada SS, Tabata I, et al. Calf circumference as a surrogate marker of muscle mass for diagnosing sarcopenia in Japanese men and women. Geriatr Gerontol Int 2015;15:969-76. doi: 10.1111/ggi.12377.
18. Bruschi C, Cerveri I, Zoia MC, Fanfulla F, Fiorentini M, Casali L, et al. Reference values of maximal respiratory mouth pressures: A population-based study. Am Rev Respir Dis 1992;146:790-3. doi: 10.1164/ajrccm/146.3.790.
19. Jung HY, Park BK, Shin HS, Kang YK, Pyun SB, Paik NJ, et al. Development of the Korean Version of Modified Barthel Index (K-MBI): Multi-center study for subjects with stroke. J Korean Acad Rehabil Med 2007;31:283-97.
20. McArthur K, Fan Y, Pei Z, Quinn T. Optimising outcome assessment to improve quality and efficiency of stroke trials. Expert Rev Pharmacoecon Outcomes Res 2014;14:101-11. doi: 10.1586/14737167.2014.870479.
21. Verheyden G, Nieuwboer A, Mertin J, Preger R, Kiekens C, De Weerdt W. The Trunk Impairment Scale: A new tool to measure motor impairment of the trunk after stroke. Clin Rehabil 2004;18:326-34. doi: 10.1191/0269215504cr733oa.
22. Yao R, Yao L, Rao A, Ou J, Wang W, Hou Q, et al. Prevalence and risk factors of stroke-related sarcopenia at the subacute stage: A case control study. Front Neurol 2022;13:899658. doi: 10.3389/fneur.2022.899658.
23. Lage VKDS, de Paula FA, Dos Santos JM, Costa HS, da Silva GP, Lima LP, et al. Are oxidative stress biomarkers and respiratory muscles strength associated with COPD-related sarcopenia in older adults? Exp Gerontol 2022;157:111630. doi: 10.1016/j.exger.2021.111630.
24. Matsushita T, Nishioka S, Taguchi S, Yamanouchi A. Sarcopenia as a predictor of activities of daily living capability in stroke patients undergoing rehabilitation. Geriatr Gerontol Int 2019;19:1124-8. doi: 10.1111/ggi.13780.
25. Yoshimura Y, Wakabayashi H, Bise T, Nagano F, Shimazu S, Shiraishi A, et al. Sarcopenia is associated with worse recovery of physical function and dysphagia and a lower rate of home discharge in Japanese hospitalized adults undergoing convalescent rehabilitation. Nutrition 2019;61:111-8. doi: 10.1016/j.nut.2018.11.005.
26. Nagano F, Yoshimura Y, Bise T, Shimazu S, Shiraishi A. Muscle mass gain is positively associated with functional

recovery in patients with sarcopenia after stroke. J Stroke Cerebrovasc Dis 2020;29:105017. doi: 10.1016/j.jstrokecerebrovasdis.2020.105017.
27. Sutbeyaz ST, Koseoglu F, Inan L, Coskun O. Respiratory muscle training improves cardiopulmonary function and exercise tolerance in subjects with subacute stroke: A randomized controlled trial. Clin Rehabil 2010;24:240-50. doi: 10.1177/0269215509358932.
28. Fan Q, Jia J. Translating research into clinical practice: Importance of improving cardiorespiratory fitness in stroke population. Stroke 2020;51:361-7. doi: 10.1161/STROKEAHA.119.027345.
29. Zhang X, Zheng Y, Dang Y, Wang L, Cheng Y, Zhang X, et al. Can inspiratory muscle training benefit patients after stroke? A systematic review and meta-analysis of randomized controlled trials. Clin Rehabil 2020;34:866-76. doi: 10.1177/0269215520926227.
30. Menezes KK, Nascimento LR, Avelino PR, Alvarenga MTM, Teixeira-Salmela LF. Efficacy of interventions to improve respiratory function after stroke. Respir Care 2018;63:920-33. doi: 10.4187/respcare.06000.
31. Charususin N, Gosselink R, McConnell A, Demeyer H, Topalovic M, Decramer M, et al. Inspiratory muscle training improves breathing pattern during exercise in COPD patients. Eur Respir J 2016;47:1261-4. doi: 10.1183/13993003.01574-2015.
32. Lage SM, Pereira DAG, Corradi Magalhães Nepomuceno AL, Castro AC, Araújo AG, Hoffman M, et al. Efficacy of inspiratory muscle training on inspiratory muscle function, functional capacity, and quality of life in patients with asthma: A randomized controlled trial. Clin Rehabil 2021;35:870-81. doi: 10.1177/0269215520984047.
33. Woods A, Gustafson O, Williams M, Stiger R. The effects of inspiratory muscle training on inspiratory muscle strength, lung function and quality of life in adults with spinal cord injuries: A systematic review and Meta-analysis. Disabil Rehabil 2023;45:2703-14. doi: 10.1080/09638288.2022.2107085.
34. Landi F, Liperoti R, Russo A, Giovannini S, Tosato M, Capoluongo E, et al. Sarcopenia as a risk factor for falls in elderly individuals: Results from the ilSIRENTE study. Clin Nutr 2012;31:652-8. doi: 10.1016/j.clnu.2012.02.007.
35. Lee K, Cho JE, Hwang DY, Lee W. Decreased respiratory muscle function is associated with impaired trunk balance among chronic stroke patients: A cross-sectional study. Tohoku J Exp Med 2018;245:79-88. doi: 10.1620/tjem.245.79.
36. Bosnak-Guclu M, Arikan H, Savci S, Inal-Ince D, Tulumen E, Aytemir K, et al. Effects of inspiratory muscle training in patients with heart failure. Respir Med 2011;105:1671-81. doi: 10.1016/j.rmed.2011.05.001.
37. Boz K, Saka S, Çetinkaya İ. The relationship of respiratory functions and respiratory muscle strength with trunk control, functional capacity, and functional independence in post-stroke hemiplegic patients. Physiother Res Int 2023;28:e1985. doi: 10.1002/pri.1985.
38. Tovar-Alcaraz A, de Oliveira-Sousa SL, León-Garzón MC, González-Carrillo MJ. Effects of inspiratory muscle training on respiratory function and balance in stroke survivors: A randomized controlled trial. Rev Neurol 2021;72:112-20. Spanish. doi: 10.33588/rn.7204.2020532.
39. Farrero E, Antón A, Egea CJ, Almaraz MJ, Masa JF, Utrabo I, et al. Guidelines for the management of respiratory complications in patients with neuromuscular disease. Sociedad Española de Neumología y Cirugía Torácica (SEPAR). Arch Bronconeumol 2013;49:306-13. English, Spanish. doi: 10.1016/j.arbres.2012.12.003.
40. Frankenstein L, Nelles M, Meyer FJ, Sigg C, Schellberg D, Remppis BA, et al. Validity, prognostic value and optimal cutoff of respiratory muscle strength in patients with chronic heart failure changes with beta-blocker treatment. Eur J Cardiovasc Prev Rehabil 2009;16:424-9. doi: 10.1097/HJR.0b013e3283030a7e.
41. Jung JH, Shim JM, Kwon HY, Kim HR, Kim BI. Effects of abdominal stimulation during inspiratory muscle training on respiratory function of chronic stroke patients. J Phys Ther Sci 2014;26:73-6. doi: 10.1589/jpts.26.73.
42. Cho JE, Lee HJ, Kim MK, Lee WH. The improvement in respiratory function by inspiratory muscle training is due to structural muscle changes in patients with stroke: A randomized controlled pilot trial. Top Stroke Rehabil 2018;25:37-43. doi: 10.1080/10749357.2017.1383681.