RESEARCH PAPER

Effectiveness of Liuzijue Qigong in Improving Ventilatory Function among Older Adults with subacute Stroke: A Randomized Controlled Trial

Aia Muhammad Ibrahem[1*], MSc; Sara S. El-Din[2], PhD; Nagwa Ibrahim Rehab[3], PhD; Ghada Saed AbdelAzim[4], PhD; Azza Abdelaziz Abdelhady[5], PhD; Gehad Ali Abd-Elhaseeb[5], PhD

1. Department of Physical Therapy for Cardiovascular/Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Sinai University, Egypt. (corresponding author)
aiamuhammed90@gmail.com
2. Department of Physical Therapy, College of Applied Medical Sciences, Najran University, Najran, Saudi Arabia.
Sara.salah.ssed@gmail.com
3. Department of Physical Therapy for Neurology and Neurosurgery, Faculty of Physical Therapy, Cairo University, Giza, Egypt.
nagwa1102010@yahoo.com
4. Department of Neurology, Faculty of Medicine (for Girls), Al-Azhar University, Cairo, Egypt.
ghada_saed2006@yahoo.com
5. Department of Physical Therapy for Cardiovascular/Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Cairo University, Giza, Egypt.
azzaabdelaziz1160@gmail.com
Gehad Ali Abd-Elhaseeb
Dr.gpt111@cu.edu.eg

ABSTRACT

Objective: to find out the impact of Liuzijue exercises on pulmonary function among Older Adults with subacute Stroke.

Participants: 70 Older Adults with subacute Stroke, were randomized equally to either the Liuzijue or control group.

Intervention: Individuals allocated to the intervention cohort underwent Liuzijue exercise five sessions weekly, each lasted twenty minutes, in addition to conventional rehabilitation therapy delivered three times weekly for forty-five to sixty minutes per session, across twelve weeks.

Main Outcome Measures: Variables were evaluated both at the beginning and end of the research. Forced Expiratory Volume in one second (FEV_1) as the primary outcome. Secondary pulmonary outcomes included Forced Vital Capacity (FVC), the FEV_1/FVC ratio, and Maximum Voluntary Ventilation (MVV). all measured using spirometry.

Results: Both groups demonstrated significant improvement over time across all measured variables compared with baseline (all $p < .001$). However, the mixed ANOVA yielded larger treatment effects in the intervention group for FEV_1 ($p = .027$), FVC ($p = .001$), and MVV ($p = .012$), with corresponding between-group mean differences of 0.40 L, 0.46 L, and 16.13 L/min, respectively. In contrast, no significant Time × Group interaction was observed for the FEV_1/FVC ratio ($p = .554$), indicating comparable changes between the two groups.

Conclusions: Liuzijue exercise may be an effective adjunct intervention for improving ventilatory function in older adults with stroke.

Keywords: Stroke – Older Adults – Liuzijue – ventilatory Function – Spirometry

ABBREVIATIONS

ADL	Activities of Daily Living.
BMI	Body Mass Index
COPD	Chronic obstructive pulmonary disease
CVA	Cerebrovascular Accident
DALYs	Disability-Adjusted Life Years
FEV_1	Forced expiratory volume in one second
FVC	Forced vital capacity
MVV	Maximal voluntary ventilation

How to cite this article: Ibrahem AM, El-Din SS, Rehab NI, AbdelAzim GS, Abdelhady AA, Abd-Elhaseeb GA. Effectiveness of Liuzijue Qigong in improving ventilatory function among older adults with subacute stroke: a randomized controlled trial. Int J Drug Deliv Technol. 2026;16(79s): 249-257. DOI: 10.25258/ijddt.16.79s.28

INTRODUCTION

Respiratory dysfunction is a common yet frequently overlooked consequence of stroke and may substantially affect recovery and life quality. Stroke-related motor impairment can reduce chest wall mobility and respiratory muscle efficiency, thereby compromising pulmonary function.[1,2] Although respiratory muscle dysfunction is clinically important, it remains relatively underexplored in the literature. Evidence from recent studies indicates that individuals with stroke, during both the acute and chronic stages, exhibit lower respiratory muscle strength than healthy individuals.[3] Consequently, stroke survivors commonly demonstrate reduced pulmonary function, and lung volumes.[4]

A stroke, also referred to as a cerebrovascular accident (CVA), is a medical condition resulting from an interruption or abnormality in the cerebral blood supply that leads to brain injury.[5] It is among the most prevalent neurological conditions.[6] 5.65% of disability-adjusted life years (DALYs) and 11.59% of all fatalities are caused by stroke, making it the greatest cause of death and disability worldwide.[5] The most significant non-adjustable risk element for stroke is age, with its incidence gradually rising after age 55. As the elderly population continues to grow, the prevalence of stroke is anticipated to rise, accordingly.[7]

The clinical manifestations and severity of stroke are influenced by the location and size of the lesion, as well as the extent of collateral circulation,[4] resulting in a wide spectrum of neurological deficits and functional impairments.[8,9]

Liuzijue Qigong is Originating from traditional Chinese medicine,[10] it is a low-intensity mind-body exercise that has been investigated as an adjunct rehabilitation strategy for older adults and geriatric populations.[11,12] A classic style of Qigong is called Liuzijue Qigong (LQG) that combines six characteristic breathing, sounds with coordinated body movements, breathing regulation, postural control, and meditation to promote health, well-being, and physical function.[13,14]

Therefore, this study was conducted to evaluate the effectiveness of Liuzijue Qigong on ventilatory function in stroke survivors. The main outcome was FEV_1, whereas the additional outcomes were FVC, the FEV_1/FVC ratio, and MVV. The null hypothesis was that Liuzijue Qigong would have no significant effect on ventilatory function in stroke survivors compared with conventional rehabilitation.

METHODS

Ethical approval

Ethical authorization was given by the Research Ethics Committee of Cairo University's Faculty of Physical Therapy (permission No. P.T.REC/012/005865). The study protocol (Identifier: NCT07153562) was prospectively filed on ClinicalTrials.gov.[15]

Study design

A two-arm, parallel-group, single-blind, randomized controlled study

Participants

Following a doctor's referral, participants were gathered from the outpatient physical therapy clinic of a specialized public hospital between August 25, 2025, and March 1, 2026. Prior to participation, all eligible individuals provided written informed consent. Physiotherapists used the predetermined inclusion and exclusion criteria to assess eligibility.

Inclusion criteria

Patients were eligible if they had a medically stable unilateral subacute stroke, were 60–80 years of age, and were capable of understanding and following simple verbal commands.

exclusion criteria

Patients who were smokers at the time were not included. or had severe psychological disorders, active hemoptysis, untreated pneumothorax, hemodynamic instability, impaired consciousness, or chronic unstable pulmonary and/or cardiac disease, as well as those receiving chemotherapy, were also excluded.

Sample size calculation

The sample size was determined using G*Power v3.1.9.7. An effect size of 0.83 for FEV_1 (Cohen's d), derived from pooled estimates reported in a previous meta-analysis,16 was used for the calculation. Assuming a two-tailed independent t-test with a type I error of 5% and 90% power, the minimum required sample comprised 64 participants. To minimize the impact of possible withdrawals, the final study included 70 participants, equally distributed between the two groups.

Randomization and allocation

Randomization assigned 70 participants equally to the groups under intervention and control (35 per group). All participants completed the study without dropout, and outcome analyses were conducted according to the initial group assignment.

INTERVENTIONS

Intervention group

Participants assigned to the intervention group completed a supervised Liuzijue Qigong program consisting of five sessions per week for 12 consecutive weeks, each session lasted approximately 20 minutes.[17] In addition, they underwent conventional rehabilitation therapy three times weekly, with session durations ranging from 45 to 60 minutes, throughout the same 12-week intervention period.[18]

Technique[19]

For all sounds, patients stood with feet shoulder-width apart. The specific movements were as follows:

1. "Xu": While inhaling, individuals raise their upper limbs laterally and vertically until overhead, maintaining palm-to-palm alignment. This is followed by an exhalation phase marked by the 'Xu' sound, wherein the palms are rotated downward and the arms are smoothly retracted through a circular trajectory toward the anterior aspect of the trunk.

2. "He": As participants inhale, they raise their arms laterally from their flanks to chest level with palms facing upward. This action transitions into an exhalation coordinated with the 'He' vocalization, wherein the hands are pushed forward and slightly upward in a presentation-like posture, concluding with the limbs gently drifting downward to resume their initial position by the body.

3. "Hu": Inhalation coincides with a sagittal plane elevation of the hands, oriented with palms facing the floor, reaching the level of the chest. The transition to exhalation incorporates the 'Hu' vocalization alongside a controlled downward excursion of the upper limbs toward the abdominal wall, mimicking a gentle pushing action, after which the arms are released to float downward back to the lateral baseline.

4. "Si": Inhalation accompanies the vertical ascent of the hands along the anterior aspect of the body, whereupon the palms are turned outward to perform a soft, outward-pressing gesture. The sequence concludes as the upper limbs are slowly retracted and lowered downward to the lateral sides of the body.

5. "Chui": During inhalation, individuals shift their hands toward the lower back with inward-facing palms. The subsequent exhalation incorporates the 'Chui' phonetic sound, a mild forward bend of the upper body, and a downward pressing motion of the hands toward the floor, after which the participants resume a straight posture and lower their arms back to the sides.

6. "Xi": Inhalation accompanies the vertical ascent of the hands to chest height, maintaining upward-facing palms. The sequence proceeds with an exhalation phase marked by the 'Xi' sound, a lateral outward turn of the palms, and a soft pushing gesture away from the trunk, after which the arms are slowly retracted and lowered downward to the sides of the body.

Control group

For a duration of twelve weeks, participants in the control arm underwent standard physical therapy under professional supervision, consisting of three weekly sessions lasting 45 to 60 minutes each. [19] In alignment with established post-stroke care recommendations[20], this conventional regimen prioritized multi-disciplinary management, functional mobility training, and task-specific drills designed to optimize motor performance, balance, and independence. Specifically, the routine comprised muscle strengthening, flexibility stretching, postural balance exercises, aerobic activities, and gait re-education.

OUTCOMES

Baseline demographic data (age, sex, and BMI) were collected for all participants through in-person evaluations. Clinical outcome measures, including FEV_1, FVC, FEV_1/FVC ratio, and MVV, were assessed by result evaluators who are blindfolded at baseline and after the 12-week intervention.

primary outcome

FEV_1 was designated as the primary outcome measure and was assessed using handheld spirometry.[21] Spirometric assessments were performed according to ATS/ERS recommendations using the best of three reproducible trials.[22] Participants performed forced expiratory maneuvers from maximal inspiration to full expiration while seated upright.[23]

secondary outcomes

Secondary pulmonary outcomes included FVC, FEV_1/FVC ratio, and MVV, which were obtained during the same spirometric assessment session.[23,24] For MVV assessment, participants performed rapid and deep breathing maneuvers for 15 seconds, and the results were expressed in liters per minute.[24]

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics (version 25). Baseline comparisons were performed using independent-samples t-tests and Chi-square or Fisher's exact tests. Outcome measures were analyzed using a two-way mixed repeated-measures ANOVA. Statistical significance was set at $p < 0.05$.

RESULTS

Baseline comparisons confirmed no significant between-group differences across all outcome measures (all $p > .05$) (Table 1).

Table 1. Participants in the intervention and control groups' initial anthropometric and demographic data

Variables	Intervention group (n = 35)	Control group (n = 35)	Test of significance	*P*-value
Age (Years)	69.66 ± 6.64	68.89 ± 6.27	0.50	0.618
Sex, N (%) Male Female	 17 (48.6%) 18(51.4%)	 17 (48.6%) 18 (51.4%)	0	1.0

Weight (kg)	75.34 ± 8.63	76.43 ± 8.75	0.52	0.603
Height (cm)	167.31 ± 7.73	167.43 ± 6.74	0.07	0.947
BMI (kg /m^2)	26.93 ± 2.71	27.24 ± 2.35	0.51	0.612

Abbreviations: BMI= body mass index; **SD**= standard deviation.

Both groups demonstrated significant improvements over time in all pulmonary function measures (all $p < .001$). However, the intervention group showed superior improvement in FEV_1, FVC, and MVV, as confirmed by significant Time × Group interaction effects ($p = .027$, .001, and .012, respectively). In contrast, no significant interaction was detected for the FEV_1/FVC ratio ($p = .554$), indicating a comparable pattern of change between the two groups. Detailed statistical results are presented in Table 2.

Table 2. Effects of intervention on pulmonary function and functional capacity: two-way mixed ANOVA results

Variable	Group	Mean ± SD		Time Effect		Interaction Effect (Time × Group)			MD (95% CI)
		Pre	Post	F	p	F	P	η^2p	
FEV_1 (L)	Intervention	1.10 ± 0.41	2.14 ± 0.42	144.2	< .001	5.128	.027	.070	0.40 (0.13 to 0.67)
	Control	1.03 ± 0.40	1.74 ± 0.42						
FVC (L)	Intervention	1.75 ± 0.49	2.70 ± 0.45	82.73	< .001	11.14	.001	.141	0.46 (0.17 to 0.75)
	Control	1.80 ± 0.42	2.24 ± 0.45						
FEV_1/FVC (%)	Intervention	55.97 ± 11.15	79.25 ± 5.49	228.8	< .001	0.353	.554	.005	2.31 (-0.91 to 5.53)
	Control	55.42 ± 11.79	76.94 ± 4.34						
MVV (L/min)	Intervention	42.12 ± 16.62	85.71 ± 16.71	154.7	< .001	6.747	.012	.090	16.13 (5.28 to 26.98)
	Control	41.05 ± 16.15	69.58 ± 16.70						

Abbreviations: SD = standard deviation; **F** = F-statistic from repeated-measures two-way mixed ANOVA; **p** = p-value; η^2p = partial eta-squared for the Time × Group interaction effect; **MD (95% CI) =** estimated marginal mean difference (post-intervention); **FEV_1** = forced expiratory volume in 1 second; **FVC** = forced vital capacity; **MVV** = maximum voluntary ventilation.

DISCUSSION

The present trial examined whether adding Liuzijue Qigong to conventional rehabilitation could enhance ventilatory outcomes in elderly individuals recovering from stroke. Our findings demonstrated significant improvements in pulmonary function in both the intervention and control groups after 12 weeks of training. Nonetheless, pulmonary outcomes such as FEV_1, FVC, and MVV demonstrated greater improvement in the intervention group suggesting an additional benefit of liuzijue beyond conventional rehabilitation.

The structural features of the interventions may be connected to this discrepancy. Conventional respiratory rehabilitation primarily focused on basic exercises, whereas liuzijue incorporates coordinated breathing patterns, vocalization, and synchronized whole-body movements with diaphragmatic control. This multimodal integration may have provided a more comprehensive respiratory and neuromuscular training stimulus compared with conventional breathing exercises alone.[13,14] which may have contributed to the greater ventilatory adaptation seen within the group receiving intervention.

The primary outcome (FEV_1) significantly enhanced within the intervention group compared with the control group (MD = 0.40 L). The magnitude of improvement was comparable to MCID thresholds reported in previous respiratory rehabilitation literature.[25] These findings suggest potential clinical relevance in addition to statistical significance.

However, the magnitude of improvement noted in the current investigation was relatively large compared with previous post-stroke respiratory rehabilitation studies and should be interpreted cautiously. In addition, the significant Time × Group interaction supports the finding that the intervention group achieved greater improvement over time in contrast to the control group.

The substantial improvement observed in both groups may partly reflect spontaneous neuroplastic recovery during the subacute post-stroke phase.[26,27] The magnitude of improvement may also be related to the relatively high intervention dose received by both groups, as greater training duration and intensity have been associated with larger respiratory gains.[30] Baseline respiratory impairment may have allowed greater improvement potential, as individuals with lower initial pulmonary function often demonstrate larger relative gains following targeted rehabilitation, reflecting reduced ceiling effects and increased responsiveness to intervention.[4] Consequently, baseline status may have contributed to the magnitude of the observed effects.

The impact of liuzijue on pulmonary function and functional independence among elderly post-stroke patients remains under-researched; however, similar physiological effects have been reported in other populations.

A recently published meta-analysis has shown that Liuzijue markedly enhanced FEV_1, as well as the FEV_1/FVC ratio among COPD patients relative to standard treatment.[29] These consistent findings underscore the efficacy of integrating Liuzijue as an adjunctive method to improve ventilatory function among elderly post-stroke patients. Its mechanisms emphasize pursed-lip and diaphragmatic breathing, lowering respiratory rate and facilitating prolonged and controlled exhalation, which may improve breathing efficiency and expiratory control.[30]

A 2025 study indicated that LQG was more effective than conventional exercises in enhancing Parkinson's patient's respiratory function. Post-treatment, the test group displayed substantial improvements in FVC and FEV_1 which were statistically superior to the control group.[31] The combination of coordinated movements with controlled sound production may engage accessory respiratory muscles, improve neuromuscular coordination, and provide low-intensity aerobic stimulation that enhances respiratory endurance, ventilatory efficiency, and exercise capacity.[32,33]

On the other hand, Zheng et al. (2021) contrasted liuzijue with regular breathing exercises among those who were just starting to recover from a stroke and found no substantial variations among the two groups regarding FEV_1 ($p = 0.24$) or FVC ($p = 0.43$).[34] The discrepancy between the studies is likely attributable to differences in participant characteristics, recovery stage, treatment dosage, and the duration of the intervention protocols.

It is also important to consider that spirometric measures are highly effort-dependent, and recalling maximal effort may be impacted by familiarity with the testing process.[35] Repeated spirometry experiences enhance the learnability of maneuvers through prior exposure.[36] MVV reflects global ventilatory performance and is influenced by respiratory muscle function and test familiarity, particularly in rehabilitation settings.[37,38] The greater improvement observed in MVV may also reflect enhanced respiratory muscle endurance and ventilatory coordination, as MVV represents integrated ventilatory performance rather than isolated airway function.[49]

From a clinical perspective, Liuzijue Qigong represents a feasible complementary intervention that may improve respiratory performance during post-stroke rehabilitation, particularly in older adults; however, larger multicenter studies with longer follow-up and mechanistic investigations are still needed to confirm the sustainability and underlying mechanisms of these effects.

Study Limitations

When evaluating the current findings, a number of limitations should be taken into account. The relatively modest sample amount may reduce the external validity of the results. In addition, the limited number of published studies investigating LQG restricts direct comparison with existing evidence. The brief duration of follow-up also precludes evaluation of the long-term sustainability of the LQG effects. Furthermore, the study enrolled only elderly individuals within the first six months after stroke, a stage characterized by neuroplasticity and spontaneous motor recovery. As a result, although the LQG intervention produced significant improvements, distinguishing its specific contribution from the natural recovery process remains challenging.

CONCLUSIONS

In conclusion, incorporating liuzijue into standard rehabilitation programs may contribute to improvements in Ventilatory Function among Older Adults with subacute Stroke. According to the results, liuzijue may be used in addition to traditional therapy. The amount of improvement shown should be taken cautiously, though, and more extensive multicenter research is required to validate these results and elucidate the processes behind post-stroke recovery.

REFERENCES

1. McGlinchey MP, James J, McKevitt C, Douiri A, Sackley C. The effect of rehabilitation interventions on physical function and immobility-related complications in severe stroke: a systematic review. BMJ Open. 2020;10(2):e033642. Published 2020 Feb 5. doi:10.1136/bmjopen-2019-033642
2. Kilbride C, Kneafsey R, Kean V. Management of physical impairments post-stroke. In: Stroke Nursing. Wiley-Blackwell; 2019:177-202.
3. Pozuelo-Carrascosa DP, Carmona-Torres JM, Laredo-Aguilera JA, Latorre-Román PÁ, Párraga-Montilla JA, Cobo-Cuenca AI. Effectiveness of Respiratory Muscle Training for Pulmonary Function and Walking Ability in Patients with Stroke: A Systematic Review with Meta-Analysis. Int J Environ Res Public Health. 2020;17(15):5356. Published 2020 Jul 24. doi:10.3390/ijerph17155356
4. Liu YT, Liu XX, Liu YQ, et al. Effects of respiratory muscle training on post-stroke rehabilitation: A systematic review and meta-analysis. World J Clin Cases. 2024;12(20):4289-4300. doi:10.12998/wjcc.v12.i20.4289
5. Luo Y, Yu G, Liu Y, Zhuge C, Zhu Y. Sleep quality after stroke: A systematic review and meta-analysis. Medicine (Baltimore). 2023;102(20):e33777. doi:10.1097/MD.0000000000033777
6. Khazaei S, Ayubi E, Khazaei M, Khazaei M, Afrookhteh G. Sleep Quality and Related Determinants among Stroke Patients: A Cross-Sectional Study. Iran J Psychiatry. 2022;17(1):84-90. doi:10.18502/ijps.v17i1.8052
7. Yousufuddin M, Young N. Aging and ischemic stroke. Aging (Albany NY). 2019;11(9):2542-2544. doi:10.18632/aging.101931
8. Rost NS, Brodtmann A, Pase MP, et al. Post-Stroke Cognitive Impairment and Dementia. Circ Res. 2022;130(8):1252-1271. doi:10.1161/CIRCRESAHA.122.319951
9. Dulyan L, Talozzi L, Pacella V, Corbetta M, Forkel SJ, Thiebaut de Schotten M. Longitudinal prediction of motor dysfunction after stroke: a disconnectome study. Brain Struct Funct. 2022;227(9):3085-3098. doi:10.1007/s00429-022-02589-5
10. McGee RW. Tai Chi, Qigong and the treatment of arthritis. Biomed J Sci Tech Res. 2021;37(5):29724-29734.
11. Chang PS, Knobf T, Oh B, Funk M. Physical and Psychological Health Outcomes of Qigong Exercise in Older Adults: A Systematic Review and Meta-Analysis. Am J Chin Med. 2019;47(2):301-322. doi:10.1142/S0192415X19500149
12. Peng J, Wu Z, Zhong H, et al. The effect of qigong for pulmonary function and quality of life in patients with covid-19: A protocol for systematic review and meta-analysis. Medicine (Baltimore). 2020;99(38):e22041. doi:10.1097/MD.0000000000022041
13. Boaventura P, Jaconiano S, Ribeiro F. Yoga and Qigong for Health: Two Sides of the Same Coin?. Behav Sci (Basel). 2022;12(7):222. Published 2022 Jul 3. doi:10.3390/bs12070222
14. Li D, Shen M, Yang X, Chen D, Zhou C, Qian Q. Effect of weight-bearing Liuzijue Qigong on cardiopulmonary function. Medicine (Baltimore). 2023;102(8):e33097. doi:10.1097/MD.0000000000033097
15. Clinical trial: Study Details | Blinded for peer review | Effect of Liuzijue Qigong Exercises on Ventilatory Function in Post Stroke Elderly Patients | ClinicalTrials.gov

16. Xu S, Zhang D, He Q, et al. Efficacy of Liuzijue Qigong in patients with chronic obstructive pulmonary disease: A systematic review and meta-analysis. Complement Ther Med. 2022;65:102809. doi:10.1016/j.ctim.2022.102809
17. Xiao L, Duan H, Li P, Wu W, Shan C, Liu X. A systematic review and meta-analysis of Liuzijue in stable patients with chronic obstructive pulmonary disease. BMC Complement Med Ther. 2020;20(1):308. Published 2020 Oct 14. doi:10.1186/s12906-020-03104-1
18. Boyne P, Billinger SA, Reisman DS, et al. Optimal Intensity and Duration of Walking Rehabilitation in Patients With Chronic Stroke: A Randomized Clinical Trial. JAMA Neurol. 2023;80(4):342-351. doi:10.1001/jamaneurol.2023.0033
19. Chinese Health Qigong Association. Liu Zi Jue: Six Sounds Approach to Qigong Breathing Exercises. Foreign Languages Press; 2008.
20. Maček Z, Kolar M, Tučić M, Mandić M. Recommendations for physiotherapy intervention after stroke. Ann Physiother Clin. 2020;2(1):1-9.
21. Kaminsky DA, Irvin CG, eds. Pulmonary Function Testing: Principles and Practice. Springer; 2018.
22. Graham BL, Steenbruggen I, Miller MR, et al. Standardization of Spirometry 2019 Update. An Official American Thoracic Society and European Respiratory Society Technical Statement. Am J Respir Crit Care Med. 2019;200(8):e70-e88. doi:10.1164/rccm.201908-1590ST
23. Wang C, Yu L, Yang J, Wang RW, Zheng YN, Zhang Y. Effectiveness of LiuZiJue Qigong versus traditional core stability training for poststroke patients complicated with abnormal trunk postural control: study protocol for a single-center randomized controlled trial. Trials. 2020;21(1):254. Published 2020 Mar 12. doi:10.1186/s13063-020-4117-6
24. Gold WM, Koth LL. Pulmonary function testing. In: Broaddus VC, ed. Murray and Nadel's Textbook of Respiratory Medicine. 6th ed. Elsevier Saunders; 2015:407-435.
25. Donohue JF. Minimal clinically important differences in COPD lung function. COPD. 2005;2(1):111-124. doi:10.1081/COPD-200053377
26. Ferriero G, Negrini F, Salgovic L, Ronconi G. Stroke and neuroplasticity: harnessing the brain's adaptive potential for recovery. Eur J Phys Rehabil Med. 2024;60(4):549-551. doi:10.23736/S1973-9087.24.08679-9
27. Donnellan-Fernandez R, Walker MF, Godecke E, et al. Revisiting dose and intensity of training: Opportunities to enhance recovery following stroke. J Physiother. 2022;68(3):149-151. doi:10.1016/j.jphys.2022.06.002.
28. Lohse KR, Lang CE, Boyd LA. Is more better? Using metadata to explore dose–response relationships in stroke rehabilitation. Stroke. 2014;45(7):2053-2058. doi:10.1161/STROKEAHA.114.004695.
29. Liu TT, Lei MJ, Wang HP, Huang YQ, Jin CD. Efficacy of liuzijue respiratory exercise in patients with chronic obstructive pulmonary disease: a meta-analysis. TMR Non-Drug Ther. 2018;1(3):75-86.
30. Yang Y, Wei L, Wang S, et al. The effects of pursed lip breathing combined with diaphragmatic breathing on pulmonary function and exercise capacity in patients with COPD: a systematic review and meta-analysis. Physiother Theory Pract. 2022;38(7):847-857. doi:10.1080/09593985.2020.1805834
31. Yin H, Cheng O, Zhang X, et al. Effects of Liuzijue Qigong on respiratory function among patients with Parkinson's disease: a randomized clinical trial. BMC Complement Med Ther. 2025;25(1):63. Published 2025 Feb 20. doi:10.1186/s12906-025-04773-6
32. Hu J, Gao R, Wang Y, et al. Effect of Liuzijue on pulmonary rehabilitation in patients with chronic obstructive pulmonary disease: study protocol for a multicenter, non-randomized, prospective study. BMC Complement Med Ther. 2022;22(1):296. Published 2022 Nov 17. doi:10.1186/s12906-022-03789-6
33. Wu W, Liu X, Li P, Li N, Wang Z. Effect of Liuzijue Exercise Combined with Elastic Band Resistance Exercise on Patients with COPD: A Randomized Controlled Trial. Evid Based Complement Alternat Med. 2018;2018:2361962. Published 2018 Jun 11. doi:10.1155/2018/2361962
34. Zheng Y, Zhang Y, Li H, et al. Comparative Effect of Liuzijue Qigong and Conventional Respiratory Training on Trunk Control Ability and Respiratory Muscle Function in Patients at an Early Recovery Stage From Stroke: A Randomized Controlled Trial. Arch Phys Med Rehabil. 2021;102(3):423-430. doi:10.1016/j.apmr.2020.07.007

35. Krabbe J, Kotro AK, Kraus T. Effects of repetition as training and incentives on the performance in pulmonary function tests in healthy volunteers. Heliyon. 2023;9(6):e17594. Published 2023 Jun 22. doi:10.1016/j.heliyon.2023.e17594
36. Cengiz SK, Savas IK, Coskun E, Erten HÇ, Cömert SS. Conformity of spirometric tests with acceptability criteria and assessment of confounding factors in routine clinical practice. Ann Thorac Med. 2025;20(3):176-182. doi:10.4103/atm.atm_232_24
37. Otto-Yáñez M, Sarmento da Nóbrega AJ, Torres-Castro R, et al. Maximal voluntary ventilation should not be estimated from the forced expiratory volume in the first second in healthy people and COPD patients. Front Physiol. 2020;11:537. doi:10.3389/fphys.2020.00537
38. Ata G, Tunalı Van Den Berg AN, Dansuk E, Kutlutürk Yıkılmaz S, Öktem S. Inspiratory muscle training and trunk control exercises on respiratory strength and motor function in spinal muscular atrophy: randomized controlled trial. Sci Rep. 2025;15(1):1532. doi:10.1038/s41598-024-81422-x
39. Manera U, Torrieri MC, Moglia C, et al. Calculated Maximal Volume Ventilation (cMVV) as a Marker of Early Respiratory Failure in Amyotrophic Lateral Sclerosis (ALS). Brain Sci. 2024;14(2):157. Published 2024 Feb 3. doi:10.3390/brainsci14020157