Immediate Effects of Thoracic Spinal Manipulation on Pulmonary Function in Stroke Patients: A Preliminary Study

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Abstract

Objectives: The purpose of this study was to investigate the immediate effects of thoracic spinal manipulation (TSM) on pulmonary function in stroke patients.

Methods: Thirty-six volunteers with stroke (20 men, 16 women) were recruited and randomized to a TSM group (n = 18) and a sham group (n = 18). All participants underwent initial pulmonary function test and then rested supine for 10 minutes before the intervention. Pulmonary function test was repeated immediately after the intervention. Forced vital capacity, forced expiratory volume at 1 second, maximum voluntary ventilation, and residual volume were measured by a spirometer in preintervention and post-intervention.

Results: Significant between-group differences were observed in forced vital capacity and forced expiratory volume at 1 second in the TSM group ($P < .05$). No significant changes in dependent variables were seen in the sham group.

Conclusion: The pulmonary function values for patients in the TSM group were significantly enhanced with no significant improvement in maximum voluntary ventilation and residual volume. Mechanical factors may be responsible for the improved pulmonary function in the TSM group. (J Manipulative Physiol Ther 2018;41:602-608)

Key Indexing Terms: *Manipulation, Spinal; Stroke; Respiratory Function Tests*

Introduction

Stroke is a major cause of chronic disability worldwide. About 50% to 70% of affected patients show recovery of functional independence, and about 50% of these have hemiparesis.[1,2] In stroke, respiratory disorders can develop, as maintenance of normal ventilation depends on intact functional components of the neuromuscular system. Ventilatory disturbances occur when diseases affect the nervous system, the musculature, or the thoracic cage, even though the lungs are normal. As a consequence of ventilatory disturbances, stroke patients develop inadequate respiratory function.[3,4] Several studies investigated changes in respiratory function in stroke patients and found that within a few weeks after stroke, there may be changes in the tone and viscoelastic properties of muscles that results in disturbance to normal biomechanical function of the respiratory and trunk muscles.[5-8] Abnormal pulmonary function in stroke patients is an independent risk factor for cardiovascular disease and may lead to an increased risk of recurrent stroke.[9]

Pulmonary rehabilitation (PR) is a key component in stroke patient recovery. Pulmonary rehabilitation reduces disability and hospitalization and improves pulmonary function. In addition, PR has been shown to improve fatigue and dyspnea, increase exercise tolerance, and enhance health-related quality of life.[10,11] However, previous studies have failed to show any clinically significant differences in forced expiratory volume in 1 second (FEV_1) or forced vital capacity (FVC), according to the duration of the PR program. This has been attributed to the fact that much of the ventilatory disturbance after stroke is the result of secondary impairment, such as skeletal muscle and psychosocial dysfunction.[12-15] This suggests that thoracic movement and related postural control are potential targets for therapeutic intervention.

Manual therapy can decrease excessive muscle tone around joints and increase muscle length and joint mobility.[16,17] This can be achieved by using joint-based techniques, such as mobilization and manipulation or soft tissue techniques, such as massage and stretching. One form of manual therapy is spinal manipulation therapy (SMT), which uses high-velocity, low-amplitude force to move a joint complex.[18] For the purpose of this paper, thoracic spinal manipulation (TSM) is defined as a manipulation involving a “thrust” that is directed toward the thoracic

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spine. The technique is designed to increase thoracic joint mobility, which may lead to an increase in lung function. In a healthy state, greater chest wall mobility is associated with greater lung volumes.[19,20] Thoracic spinal manipulation is capable of increasing the chest wall and mobility of the intervertebral and costovertebral joints.[16,21] The authors, therefore, hypothesized that TSM would improve pulmonary function in stroke patients.

In earlier studies, manipulation therapy improves pulmonary function in patients with chronic obstructive pulmonary disease (COPD), cystic fibrosis, and asthma.[20,22-26] However, to the authors' knowledge, there have been no clinical trials in stroke patients. Therefore, a randomized controlled trial (RCT) to investigate the immediate effects of TSM on pulmonary function in stroke patients was conducted.

Methods

Participants

Thirty-six volunteers with stroke (20 males, 16 females) were recruited from the Boram rehabilitation hospital (Gyeonggi, Korea). Inclusion criteria included the following: (1) stroke at least 6 months before the study; (2) a Korean mini-mental state examination score of over 24; (3) no facial palsy and unrestricted movement of the lips; (4) an FEV_1 less than 93% of predicted normal; (5) no orthopedic, unstable cardiac conditions or no neurologic condition except stroke; (6) no receptive aphasia or history of thoracic or abdominal surgery; and (7) voluntary participation and the ability to communicate effectively.[27,28] Participants were excluded if they had any of the following: (1) history of cardiac or chronic pulmonary disease, (2) clinical signs of cardiac or pulmonary disease, (3) inability to perform the pulmonary tests, (4) use of medications that could cause dizziness, and (5) any cardiopulmonary fitness training that could affect the study results.[29] All participants read and signed the informed consent form approved by the Institutional Review Board of Sahmyook University (2-1040781-AB-N-01-2016122HR).

Procedure

This study was designed as an RCT. Thirty-six participants were randomized to TSM (n = 18) and sham groups (n = 18). The randomization process was performed using random allocation software.[30] Prior to attendance at the intervention, participants were requested to abstain from any stimulants, alcohol, coffee, or exercise for at least 2 hours. Female participants were requested to remove their bras and any tight-fitting underwear from the upper body and were provided with a clinic gown to wear for the duration of the test session.[31] All participants underwent initial pulmonary function test and then rested supine for 10 minutes before the intervention. Pulmonary function test was repeated immediately after the intervention. Two participants discontinued the trial after completing the intervention. One participant was lost to follow-up from the TSM group because of refusal to have pulmonary function test because of pain on spinal manipulation; another patient was lost to follow-up from the sham group because of inability to complete spirometry after therapy because of excessive coughing. Thus, n = 17 in the TSM group, and n = 17 in the sham group. To ensure the quality of measurements, a certified respiratory therapist conducted pulmonary function test and used American Thoracic Society guidelines.[32] The standard instruction protocol included a demonstration and familiarization trial. Pulmonary function test was performed before and after the intervention (Fig 1).

Thoracic Spinal Manipulation

The participants were in a supine position with crossed arms, so that their hands were on opposite shoulders and their elbows met in the middle; the participants were positioned as close to the edge of the table as possible. The physiotherapist's right hand was placed under the thoracic spine of the targeted motion segment (T4-T8) and was used as a fulcrum, and his body applied force through the participants' arms to produce a high velocity, low-amplitude thrust toward the thoracic spine at a targeted level by momentarily dropping his body weight. When participants exhaled, TSM was applied to the thoracic spine. If no popping or cracking sound was heard on the first attempt, the therapist repositioned the participant by adjusting the secondary levers and performed a second TSM. A maximum of 2 attempts were performed on each participant (Fig 2).[33]

Sham Therapy

The participants in the sham group were placed in the same position as those in the TSM group. The physiotherapist placed his hand under the same anatomic regions as in the TSM group and lightly palpated the thoracic spine, observing segmental restrictions but not engaging the tissues for myofascial release. The physiotherapist slowly worked his way up the thoracic spine in a manner similar to that for the TSM group, taking care not to articulate the ribs.[34]

Measurements

Pulmonary function measures, including FVC, FEV_1, the ratio of FEV_1 to FVC, and maximum voluntary ventilation (MVV) were recorded for each participant by a respiratory therapist, using a spirometer (SP-1) (Schiller, Doral, Florida). Forced vital capacity is a key indicator of restrictive respiratory disorders. The participant is seated and the nose occluded by a nose peg. The participant is asked to take the deepest breath they can and then exhale into the sensor as hard as possible for as long as possible, preferably for at least 6 seconds. The test is repeated 3 times to record average

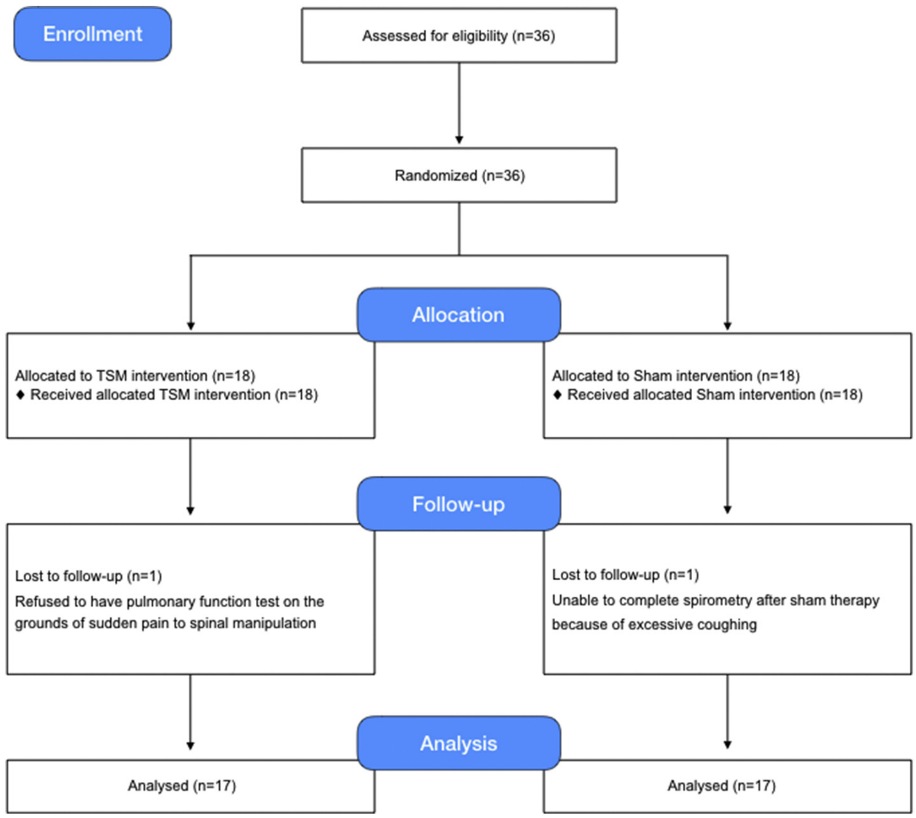

Fig 1. *CONSORT flow diagram.* TSM, *thoracic spinal manipulation.*

measurements. Forced expiratory volume at 1 second is defined as the maximum exhalation measured in 1 second and is the most useful indicator because it requires maximum effort by the participant. In an obstructive disorder, the respiratory tract closes faster than normal, and the corresponding FEV_1 decreases markedly. However, we needed to analyze and compare the ratio of FEV_1 to FVC. Generally, a disorder is considered restrictive when the ratio is more than 70% and as obstructive when less than 70%. Maximum voluntary ventilation is widely accepted as the functional variable for pulmonary function test. Maximum voluntary ventilation measures the maximum amount of air that can be inhaled and exhaled within 1 minute. However, breathing with maximum effort makes participants feel dizzy; therefore, MVV is measured over a 15-second time period for the comfort of the participant before being extrapolated to a value for 1 minute, expressed as liters per minute. The MVV test is useful in diagnosing respiratory disorders caused by other peripheral disorders.[35]

Sample Size

To determine the sample size, G-Power 3.19 software was used. To calculate sample size, α error probability and power were set as 0.05 and 0.8, respectively. In addition, the effect size was set at 0.98, based on the result of FVC in prior pilot test. Therefore, a sample size of 18 patients per group was necessary.

Statistical Analysis

All data are reported as mean ± standard deviation. Prior to intervention, the normality of data was assessed with the 1-sample Shapiro-Wilk test. Results of χ^2 analysis and the independent samples *t* test were performed on differences for all outcome variables. The paired *t* test was used to compare pulmonary function before and after intervention. The independent samples *t* test was performed to identify differences between groups. The SPSS version 19.0 statistical software for Windows (IBM Corp, Armonk, New York) was used to analyze all data, and the statistical analysis was conducted at a 95% confidence level.

Results

Pulmonary function measurements from 2 participants were incomplete, with both unable to complete spirometry after intervention: 1 from the TSM group because of sudden pain in the thoracic area and the other because of excessive coughing. Thirty-four participants completed the study.

Fig 2. *Thoracic spinal manipulation.*

Baseline characteristics for each group are listed in Table 1. Table 2 shows the mean, standard deviation, and differences between within-group pre- and post-test results of pulmonary function test (FVC, FEV_1, the ratio of FEV_1 to FVC, MVV, and residual volume [RV]) scores used in the study. No significant differences were observed in baseline values for the general characteristics or dependent variables in the 2 groups (Tables 1 and 2).

The data showed statistically significant changes from baseline to postintervention for FVC and FEV_1 in the TSM group (mean change: 1.58 ± 0.64 to 2.14 ± 0.76; $P = .009$, and 1.37 ± 0.52 to 1.94 ± 0.68; $P = .003$, respectively). No significant changes in dependent variables were seen in the sham group. Significant between-group differences were observed in FVC ($P = .019$) and FEV_1 ($P = .013$) in the TSM group.

Table 1. *Baseline Characteristics of Participants*

	TSM Group (n = 17)	Sham Group (n = 17)
Sex (male/female)	17 (10/7)	17 (9/8)
Age (y)	60.17 ± 9.64	60.92 ± 9.15
Height (cm)	166.00 ± 5.41	161.33 ± 5.06
Weight (kg)	63.67 ± 8.15	62.83 ± 6.71
FEV_1 % pred	75.00 ± 21.84	67.74 ± 27.66
BMI (kg/m^2)	24.69 ± 3.16	23.87 ± 3.00

BMI, body mass index; *FEV_1% pred*; the predicted percentage of forced expiratory volume in 1 second; *TSM*, thoracic spinal manipulation.

Discussion

In this preliminary study of 34 participants with stroke, a statistically significant and clinically meaningful improvement was demonstrated in FVC and FEV_1 in the TSM group after treatment directed to the middle thoracic zygapophyseal articulations, bilaterally. No significant between-group or within-group differences were found for MVV and RV. A minimal clinically important difference (MCID) provides a guide as to whether an intervention provides a minimum level of perceived benefit and moves beyond the concept of statistical differences.[36] Regulators consider MCID for FVC and FEV_1 as a change within 5% to 10% from baseline or 200 mL in COPD.[36,37] Minimal clinically important difference for static lung volumes has not been defined in stroke. However, compare to MCID in COPD, the results in this study have shown changes of FVC (550 mL) and FEV_1 (570 mL) in TSM group. Therefore, it is suggested that these changes in FVC and FEV_1 in this study have clinically important differences in stroke.

Spinal manipulation not only increases joint mobility but also decreases muscle hypertonicity associated with the joints.[16,21] Applying spinal manipulation would increase thoracic cage motion and decrease muscle tone locally. According to Li et al,[38] the exact mechanism by which TSM increased spirometry values and chest expansion

Table 2. *Preintervention and Postintervention Lung Volumes*

	TSM Group (n = 17)			Sham Group (n = 17)		
Variables	Pre	Post	Post-pre	Pre	Post	Post-pre
FVC (L)	1.58 (0.64)	2.14 (0.76) [a]	0.55(0.61) [b]	1.75 (0.89)	1.75 (0.72)	0.00 (0.45)
FEV_1 (L)	1.37 (0.52)	1.94 (0.68) [a]	0.57 (0.51) [b]	1.55 (0.82)	1.61 (0.69)	0.05 (0.41)
FEV_1/FVC (%)	87.23 (8.96)	90.66 (7.31)	3.43 (8.50)	88.18 (8.87)	91.57 (7.57)	3.39 (6.70)
MVV (L/min)	30.58 (15.82)	37.39 (17.53)	6.80 (11.26)	28.85 (15.10)	33.86 (20.89)	5.01 (11.58)
RV (L)	4.37 (2.09)	4.42 (2.81)	-0.05 (0.42)	5.21 (1.68)	5.15 (2.01)	0.06 (0.22)

FEV_1, forced expiratory volume in 1 second; *FVC*, forced vital capacity; *MVV*, maximum voluntary ventilation; *RV*, residual volume; *TSM*, thoracic spinal manipulation.
[a] Means significant difference within group.
[b] Means significant difference between groups.

responsible for positive results was the result of a combination of biomechanical muscular reflexogenic effects. Applying TSM would alter the overall contribution of the posterior elements to chest wall mobility. In the case of stroke, an increase in the mobility of any of the posterior components of the chest wall would lessen asymmetry of the thorax between paretic and healthy sides. Decreasing asymmetry of the thorax and associated muscle tone permit an increase in inspiratory muscle length, improving muscle efficiency, and reducing the level of muscle fatigue. Therefore, we hypothesized that it would be possible to improve FVC, FEV_1, and the ratio of FEV_1 to FVC values in this study by decreasing the effect asymmetrical chest wall mobility has on ventilation.

In contrast, we found no statistically significant between-group differences in MVV and RV after TSM when compared with sham manipulation. A possible reason as to why MVV and RV do not produce similar increases in the other values is that the effects of TSM may not be able to sufficiently shift the balance between respiratory muscle overload and respiratory adaptation. Force and endurance is needed by respiratory muscles to increase MVV and decrease RV; however, the effects of TSM could not increase respiratory muscle efficiency. It is suggested that the lack of significant differences in RV is because TSM promotes a sudden rush of air into the lungs. This air rush may not be fully exhaled in the context of respiratory muscle weakness.

Some studies showed results for SMT in the management of COPD. Improvements in lung function (increases in FVC and FEV_1, decrease in RV) and exercise capacity (improvement in 6-minute walk test results) were reported in RCTs following a combination of SMT and exercise.[25,39] To our knowledge, this study is the first to report an RCT describing the positive effects of manipulation on pulmonary function in stroke patients. The results of this study suggest that TSM could be an effective inclusion in a PR program for stroke patients.

Limitations

This study has several precautions and methodologic limitations. Precautions include the following: (1) careful attention was needed when applying TSM to stroke patients because acute pain and pain sensitivity increased; a single patient refused to have pulmonary test after the intervention because of sudden acute pain; and (2) if the physical therapist had not specialized in manipulation, such as that performed by chiropractors, this technique would be contraindicated. Methodologic limitations include the following: (1) the participants had an improved understanding of spirometry procedures after preintervention education, which was reflected in their performance; the participants breathed more easily at the post-intervention examination because they were more familiar with the laboratory environment and less anxious and, therefore, tried harder on the pulmonary function test; (2) it was difficult to exclude the influence by age-related changes, such as RV in measurement of static lung volumes[40]; (3) the results in this study only show the short-term immediate effects on pulmonary function in stroke patients, rather than investigating long-term follow-up measurements; participants were only exposed to TSM in 1 session, and (4) this study did not evaluate changes in asymmetric trunk and muscle tone and only evaluated pulmonary function. Other outcomes are needed to support the hypothesis of this paper.

As TSM did not improve MVV and RV in this study, further research should investigate the effect of combining TSM with exercise. The combination of TSM with exercise may be more beneficial for stroke patients than exercise or TSM alone. Moreover, for more valid results, a long-term study must be carried out.

Conclusion

This study demonstrated the immediate effects of TSM on pulmonary function in stroke patients. Based on these results, the use of TSM could be an effective inclusion in

PR programs designed for stroke patients with mechanical considerations.

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This paper was supported by the Fund of the Sahmyook University. No conflicts of interest were reported for this study. Authors Sunghee Joo, PT, MS, and Yongwoo Lee, DC, PT, PhD, contributed equally to the work.

Contributorship Information

Concept development (provided idea for the research): C.-H.S., S.J.
Design (planned the methods to generate the results): C.-H.S., Y.L.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): C.-H.S.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): S.J., Y.L.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): C.-H.S., Y.L.
Literature search (performed the literature search): S.J.
Writing (responsible for writing a substantive part of the manuscript): S.J.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): C.H.-S.

Practical Applications

- Thoracic spinal manipulation seemed to improve pulmonary function in stroke patients.
- The results in this study showed minimal clinically important difference.
- The use of TSM could be an effective inclusion in pulmonary rehabilitation programs designed for stroke patients.

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