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Sujita KC
M.P.T, Kempegowda Institute of Physiotherapy, KIMS, V.V. Puram, Bangalore, Karnataka, India

Sudhakara PM
M.P.T, Lecturer, Kempegowda Institute of Physiotherapy, KIMS, V.V. Puram, Bangalore, Karnataka, India

Corresponding Author:
Sujita KC
M.P.T, Kempegowda Institute of Physiotherapy, KIMS, V.V. Puram, Bangalore, Karnataka, India

To assess the effect of respiratory muscle training on respiratory muscle strength and cardiopulmonary endurance in stair climbing activities among stroke patients

Sujita KC and Sudhakara PM

Abstract
Background: Neurological dysfunction in stroke equally affects respiratory muscles along with muscles of extremities and trunk. Pulmonary complication is major impairment following stroke which affect lung function, respiratory muscle strength, endurance and diaphragmatic movements causing fluctuation in chest expansion and resulting in chest complication.
Objective: To find the effectiveness of respiratory muscle training in respiratory muscle strength and cardiopulmonary endurance in stair climbing activities among stroke patients.
Methods: Thirty-six patients diagnosed with stroke who met the inclusion criteria participated in the study. They received respiratory muscle training with incentive spirometry and diaphragmatic weight training for 5 days per week for 6 weeks in the physiotherapy department of Kempegowda institute of physiotherapy. Training load was increased every week. The outcome of the study to evaluate the respiratory muscle strength was peak expiratory flow rate (PEFR) and cardiopulmonary endurance for stair climbing activities was Timed Up and Down Stair test (TUDS) and Modified Borg Scale (M-Borg) for dyspnea and Stroke Impact Scale 3.0 for quality of life of stroke patients. Outcome measures were measured at the baseline (0 week) and end of the intervention (6 week).
Result: Respiratory muscle strength and endurance was significantly improved with respiratory muscle training of 6 weeks. The statistical analysis showed clinically significant improvement in all the outcome measures with p value less than 0.0001 ($p<0.0001$).
Conclusion: Respiratory muscle training was effective in increasing strength and endurance of the respiratory muscles and in reducing dyspnea for people with respiratory muscle weakness post-stroke. Hence, respiratory muscle training should be included in routine rehabilitation of stroke patients in order to prevent lung complications and preserve functional capacities.

Keywords: Respiratory muscle weakness, stroke, chest-expansion, cardiopulmonary endurance, stair climbing

Introduction

Stroke is one of the leading causes of long-term disability and morbidity in the world.1In 2013, the American Heart Association/American Stroke Association updated the definition of stroke including the term ‘silent’ that describes the silent infarctions (inclusive of cerebral, spinal and retinal) and other silent hemorrhages. The main reason behind such a change was to move towards a radiological demonstration (tissue-based definition) of infarction or haemorrhage [2].

In India, the death due to stroke is high, which has one-fifth of the world’s population. The approximate age-adjusted prevalence of stroke in India is 84 to 262/100000 in rural and 334 to 424/100000 in urban areas, and the age-adjusted incidence of stroke is 135 to 152/100000 person- years [3].

Neurological dysfunction due to stroke affects not only the extremities and trunk muscles but also the respiratory muscles, causing weakness of respiratory muscles, atypical respiratory pattern, decreased respiratory volumes & ventilatory function and reduced diaphragmatic activity.

These breathing alterations & abnormal respiratory functions are related to a decrease in physical activity & may lead to dyspnea in conditions of high and even under low effort demands, which in turn, may interfere with the ability to carry out the activities of daily life and community participation [4, 5]. About 40% of the stroke survivors show decreased diaphragm movement, decreased lung function by 50% of the age-expected values, and a decreased maximal expiratory/inspiratory pressure compared with healthy individuals [6].

Respiratory muscle strength is one of the most important factors in maintaining intact lung function as weakened muscles result in decreased diaphragmatic movement and chest expansion, thus increasing mechanical resistance to respiration, and decreased ventilation and cough effectiveness, thus leading to difficulty in eliminating secretions, which significantly increases the risk of lung infections [7].

It is well known that along with respiratory weakness these patients also experience the reduced cardiorespiratory fitness and mobility [5, 8, 9]. The reduction in the cardiorespiratory fitness in the stroke patients is also predicted to be due to various causes including dysfunction in the cardiovascular system which involves both cardiac and noncardiac mechanisms, and impairment in the neuromuscular system which involve muscle paralysis, balance dysfunction, spasticity, and disuse muscle atrophy along with dysfunction in the respiratory system which involves respiratory muscle weakness or fatigue and impairment in the gas exchange systems.9 Balance and walking function is directly proportional to the cardiorespiratory fitness in patients with stroke. Since, walking performance is reduced due to high demand of hemiparetic gait, it thereby reduces the cardiopulmonary fitness [9].

Stair climbing is considered as one of the most difficult activities to perform in community dwelling older adults as it places excess demand on muscular strength, coordination, balance & cardiorespiratory fitness. Walking after stroke is considered as an important part of rehabilitation but stair climbing is not given much importance [10]. Along with walking on the flat surface, walking up and down the stairs are also the basic activities of daily living. So overall improvement in walking ability is important. One of the important goals of stroke rehabilitation must include the ability to walk independently on the flat surface, up and down the stairs, to improve functions and social activities in stroke patients [11].

Pulmonary function is essential to cardiopulmonary endurance and performances in activities of daily living in post-stroke patients. These functions are affected due to weakness in the respiratory muscle which is caused by the long-term hospitalization–induced pulmonary infection and deconditioning of the respiratory muscles that reduces the function of oxygen transport and enables patient to get fatigue easily during activities resulting in low performances in ADLs [1, 12].

In patients with primary neuromuscular disease such as stroke, dyspnea is one of the predominant symptoms,5 which is characterized by the sensation of shortness of breath, perceived when carrying- out lower or high efforts, has the potential to negatively interfere with the performance of daily living activities. It is caused due to the inadequate strength of the inspiratory musculatures which does not allow for the proper expansion of the ribcage. And this displeasing inspiration is the main reason behind it [13]. Along with the weakness of the respiratory muscles, it is also associated with sedentary lifestyles and deconditioning after stroke [5].

Diaphragm is one of the principal muscles of respiration [14] which has an involvement of performing 60-80% of inspiratory effort. The respiratory impairment in stroke involves the diaphragmatic dysfunction which indicates the inability to generate the pressure due to muscle weakness [15]. Diaphragm is morphologically & functionally a skeletal muscle. So, the physiological principle of resistance training of diaphragm is similar to other skeletal muscle. Diaphragm weight training is one of the various techniques to improve the strength and performance of the respiratory muscle, improve pulmonary function & cardiorespiratory fitness [14, 16]. It is strengthen by using abdominal weights.17 It is also easy as well as cost effective and better than other techniques [14].

Incentive Spirometry is a medical device that helps in improving the lung functions and expansion of the lungs [18, 19] by inducing sighing or yawning in patients, asking them to take long and slow deep breaths. It is considered as a safe as well as simple technique which helps in lung expansion and prevents many pulmonary complications such as atelectasis in a patient with short breathing [19]. The main benefit behind the use of incentive spirometer is that it is very easy to make patient understand about how to use the instrument and is available in affordable price. Patients also get the visual feedback while using the instrument so they may be motivated to perform it on their own and to complete the target with the feedback [1].

The peak flow meter is a simple, easy to use tool that measures peak expiratory flow (PEF) and detects airflow limitation.20Peak Expiratory Flow Rate (PEFR) is the maximum rate of airflow achieved during a forced expiration after maximal inspiration.21Compared to spirometry, peak flow measurements are less-time consuming, are not dependent on trained manpower, also a comfortable procedure for a patient to perform [20].

The Timed Up and Down Stairs was developed as a functional mobility outcome measure that would potentially reflect improvements in the musculoskeletal and neuromuscular systems that contribute to the control of posture. Timed Up and Down Stairs involves the subject ascending one flight of stairs, turning around, and descending to the starting point. One can hypothesize that performance on the Timed Up and Down Stairs requires a certain amount of strength of the lower extremities and trunk, range of motion in the lower extremities, coordination for fast reciprocal movements, and anticipatory and reactive postural control [22].

The Modified Borg Dyspnea Scale (MBS) is a 0 to 10 rated numerical score used to measure dyspnea as reported by the patient during submaximal exercise and can also be routinely administered during six-minute walk testing (6MWT) [23].

The SIS 3.0 is a 59-item self-report assessment of stroke outcome used to assess health-related quality of life. The SIS has eight domains: strength, hand function, mobility, physical and instrumental activities of daily living, memory and thinking, communication, emotion, and social participation. Scores for each domain range from 0 to 100, and higher scores indicate a better quality of life [24]. The SIS 3.0 is designed for repeated administration to track the impact of a stroke on survivors' health and life status over time. It can also be used in clinical and research applications.25The SIS has demonstrated validity and reliability for assessing health related quality of life in stroke survivors [26].

The six-minute walk test (6MWT) is a simple, widely used measure of functional capacity [27]. It is a well-tolerated test which reflects daily activities and can be easily used in clinical practice. It provides information about functional capacity, response to therapy and prognosis across a range of chronic cardiopulmonary conditions.28 There is strong evidence to support the reliability and construct validity of using the 6MWT in people after stroke. In clinical practice, the 6-minute walk test (6MWT) is often used as a sub-maximal test to assess walking capacity and cardiovascular fitness in this group of patients [29].

A valid, reliable, and responsive measure assessing poststroke motor function is essential for appropriate clinical decision-making, treatment planning, and research. The Brunnstrom recovery stages is a short and easily administered measure for assessing motor function. This was designed to describe a sequence of extremity motor recovery after stroke based on the synergy pattern of movement that develops during recovery from a flaccid limb to near-normal and normal movement and coordination. Clinicians rate a patient's stage based on the patient's spasticity and movement [30].

The cognitive disorders in the acute stage of stroke are common and powerful independent predictors of adverse outcome in the long term. Diagnosis of cognitive deficits at acute stage of stroke is necessary as it may increase the chances to early return to the work and improving quality of life when corresponding treatments were taken. Screening tests are therefore required to improve the diagnosis of poststroke cognitive impairment [31]. There are many cognitive screening tests, but Mini-Mental State Examination (MMSE) is one of the most popular and widely used. The MMSE consists of 11 tasks, and scores range from 0 to 30, with higher scores indicating better cognitive functioning. The tasks are grouped into categories, each representing a different cognitive domain: orientation, concentration, working memory, verbal memory, language, and praxis [32].

Objectives of the study

- To assess the respiratory muscles strength following respiratory muscle training.
- To assess the cardiopulmonary endurance in stair climbing activity in stroke patients following respiratory muscle training.
- To assess the effect of respiratory muscle training on dyspnea after stroke.
- To assess the effect of respiratory muscle training on quality of life after stroke.

Methods and Methodology

The study was conducted at Kempegowda institute of physiotherapy (KIPT) and the datas were collected from the Out-patient department of Physiotherapy clinic rehabilitation center, KIPT, Out- patient department and In-patient department of General Medicine in Kempegowda Institute of Medical Sciences Hospital and research Centre (KIMS), Bangalore. It was one group pre-test and post-test experimental design. Sample size was calculated 36 & the design was non-probability convenient sampling. The study duration was 12 months.

Inclusion Criteria

- Patients who had experienced the 1st episode of unilateral stroke with hemiparesis between the age group of 40 to 70 years.
- Patients in subacute phase post stroke ≤ 6 months.
- A score of 24 or higher in MMSE scale to ensure that they will understand & follow the instructions given.
- Brunnstrom recovery Stage of lower extremity ≥ 4.
- Patients who can complete 6MWT are only included.
- Subjects who are ready to participate with signed written consent.

Exclusion Criteria

- Subjects with any uncontrolled health conditions.
- Subjects with facial palsy.
- Subjects with severe cardiopulmonary disorder.
- Subjects unwilling to participate.

Methodology

The institutional ethical committee of Kempegowda Institute of Physiotherapy reviewed the study protocol and after seeking the approval and ethical clearance, datas were collected from the above- mentioned places for the study. The subjects included in the study were briefly explained about the nature of the study and the intervention included in the study in the language understood by the subject/family members. A signed informed consent was obtained in patient’s own understandable language. After the informed consent was taken from each subject, they were assessed for inclusion and exclusion criteria and those fulfilling the inclusion criteria were only included.

All the baseline data was collected such as: demographic details (name, age, gender, hand dominance, side affected and duration of stroke). Subjects were ruled out for perceptual and cognitive deficits like hemi spatial neglect; attention and memory deficits orthopaedic, vestibular, and other neurological conditions. Subjects were evaluated for cause of stroke, with Brunnstrom recovery stage of ≥ four, score of 24 points or higher of the Mini-Mental State Examination. Then, patients were asked to perform 6MWT and complete it and necessary verbal feedback was given to encourage patient to complete the test. Subjects who were able to complete 6MWT were only taken. Maintaining the privacy of the patients, all the subjects were evaluated pre and post treatment using the outcome measures of the study which were:

- PEFR (Peak Expiratory Flow Rate),
- TUDS (Timed Up and Down Stair Test),
- M-Borg (Modified Borg Dyspnea Scale),
- SIS 3.0 (Stroke Impact Scale 3.0)

Intervention

After evaluation was done, all the included subjects underwent the treatment sessions with the conventional exercises such as stretching, active range of motion exercises, Active-assisted ROM exercises and 10-15 minutes of rest time was given following which respiratory muscle training was started in the presence of therapist, which includes diaphragmatic weight training & tri-ball incentive spirometry.

Diaphragmatic weight training

To perform the diaphragmatic weight training exercise, the patients were explained about the protocol and live demonstration of the exercise was given to all subjects to ensure the maximal excursion of diaphragm during the training. The position of the patient was supine lying. Then small weights (3-5lbs) in the form of weight-cuff were placed in the epigastric region of the patient then the patients were asked to perform deep breathing exercise keeping the upper chest as quiet as possible and without the use of any accessory muscles. The training was given for five times per week for 6 weeks. The resistance was kept in such a way that it did not interfere with normal rise of abdomen during deep breathing. In this training, the weight kept on the abdomen was increased weekly as per the patient's tolerance eventually patients were encouraged to increase the time that he/she breathe against resistance of weight and the frequency of the exercise was 10 repetition per set for 2 set.

Tri-ball Incentive Spirometry

To perform this exercise, patient was made to sit in upright sitting position with the device held in hand in front of the eye. The disposable mouth piece connected in the device was placed in their mouth with tightly sealed lips. Then the patients were instructed to breathe in slowly and as deeply as possible allowing the balls in the device to rise. The rise of 3 balls will give visual feedback for the patients and encouraged them to sustain the inspirations and promote lung expansion. The procedure was performed following the clinical guidelines published by the American Association for Respiratory Care, i.e., the inspiration will be asked to perform over a period of five seconds followed by a breath-hold of 3 seconds and normal exhalation. They will be given 5 seconds of rest and repeated the steps nine more times making a total of ten repetitions followed by an additional set, making a total of 20 repetitions of two sets. Likewise, for the expiratory muscle training, the device was held upside down and the procedure was repeated as in upright position.

Then the outcome measures were calculated after the training was completed and compared with the pre-training values. The primary outcome measures were Peak Expiratory Flow Rate (PEFR) & Timed Up and Down Stair test (TUDS) whereas the secondary outcome measures were Modified Borg Dyspnea Scale (MBS) & Stroke Impact Scale 3.0 (SIS 3.0)

To obtain the value for Peak expiratory flow rate (PEFR), peak flow meter was used. Here, Patients were asked to have a light breakfast in the morning before the test and they were asked to relax in a chair for some time before performing the test. Then patients were asked to take deep breath and blow in a peak flow meter by closing both the nostrils. It was performed 3 times and the best value is recorded.

The TUDS test was performed before and after the treatment. To perform the test patient was asked to stand 30 cm from the bottom of a 14-step flight of stairs (19.5-cm step height) and were instructed to quickly, but safely go up the stairs, turn around on the top step (landing) and come all the way down until both feet land on the bottom step (landing)." The subjects were allowed to choose any method of traversing the stairs. This included using a step-to or foot over foot pattern, running up the stairs, skipping steps, or any other variation. However, all subjects faced in the direction of the movement (faced up and down stairs, not to the side) as they transverse the steps. The subjects were given the cues "ready" and "go." The TUDS score was the time in seconds from the "go" cue until the second foot returned to the bottom landing. Shorter times was indicated as better functional ability.

The Modified Borg Dyspnea Scale (MBS) is a subjective assessment scale which is administered by patient himself where patients were asked to rate their difficulty level between 0 to 10 where 0 indicated no breathlessness and 10 indicates maximal breathlessness. Here, patient were asked to rate the exertion they felt during submaximal exercise.

Since, the SIS 3.0 assesses 59 items of a patient's quality of life, divided into eight dimensions where a stroke has an overall effect on health and well-being. Here, for each domain varieties of questionnaire are available which were asked to patient in their own comfortable language and the response was recorded. Scores for each domain range from 0 to 100 where higher scores indicate a better HR-QoL. The SIS scale also included a question to assess the patient's global perception of recovery. After SIS was administered, the respondent was asked to rate their percent recovery since their stroke on visual analogue scale of 0 to 100 with 0 meaning no recovery & 100 meaning full recovery.

Statistical Analysis And Result

Data analysis was performed by SPSS (version 17) for windows. Alpha value was set as 0.05. Descriptive statistics was performed to find out mean, standard deviation, minimum, maximum, range for the demographic variable and outcome variables. Paired t test was used to find out significant difference with in group for PEFR and TUDS. Wilcoxon signed rank sum test was used to find out significant difference with in group for M-BORG and SIS. Microsoft excel, word was used to generate graph and tables.

Result

Table I: Descriptive statistics for demographic and outcome variables

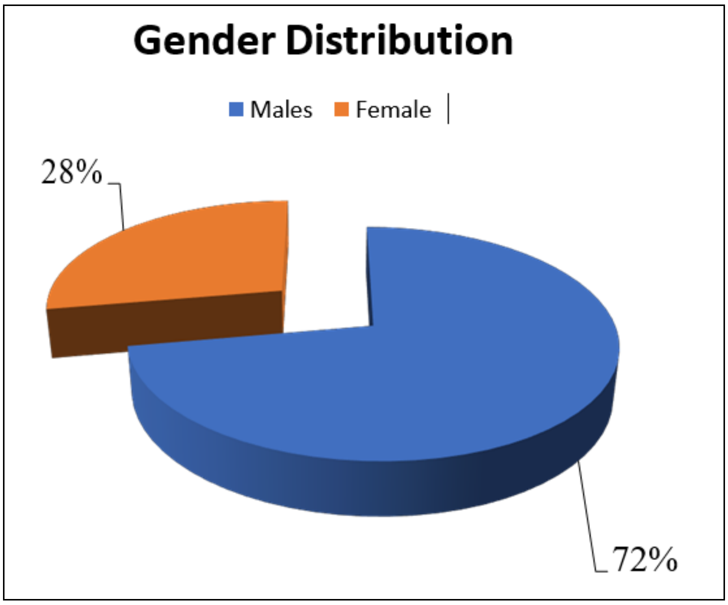
Sl. No:	Variable	Range	Mean	SD	Min	Max
1	Age	30	55.39	8.46	40	70
2	PEFR	170	292.03	44.52	210	380
3	TUDS	22	48.33	5.37	38	60
4	M-BORG	3	2.69	0.71	1	4
5	SIS 3.0	33.01	44.22	11.25	32.06	65.07

In the present study the mean age is 55.39 with standard deviation of 8.46, min of 40 and max of 70 and range of 30. In the present study the mean PEFR is 292.03 with standard deviation of 44.52, min of 210 and max of 380 and range of 170. In the present study the mean TUDS is 48.33 with standard deviation of 5.37, min of 38 and max of 60 and range of 22. In the present study the mean M-BORG is 2.69 with standard deviation of 0.71, min of 1 and max of 4 and range of 3. In the present study the mean SIS is 44.22 with standard deviation of 11.25, min of 32.06 and max of 65.07 and range of 33.01.

Table 2: Gender Distribution

SL. No.	Gender Distribution	Frequency	Percentage
1	Males	26	72.2
2	Female	10	27.8
Total		36	100

In the present study, there were 26 males (72.2%) and 10 females (27.8%). This indicates more male subjects were compared to females.

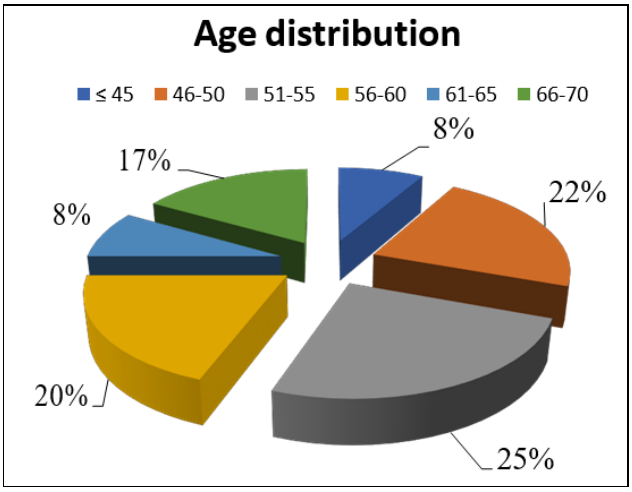


Graph 1: Gender Distribution

Table 3: Age distribution

Sl. No:	Age distribution	Frequency	Percentage
1	≤ 45	3	8.3
2	46-50	8	22.2
3	51-55	9	25.0
4	56-60	7	19.4
5	61-65	3	8.3
6	66-70	6	16.7

In the present study, the common age group who presents in this study belong to 51-55 yrs (25.0%) followed by 46-50yrs (22.2%) followed by 56-60 yrs (19.4%) followed by 66-70 yrs (16.7%) followed by 61-65 and less than 45yrs (8.3%).

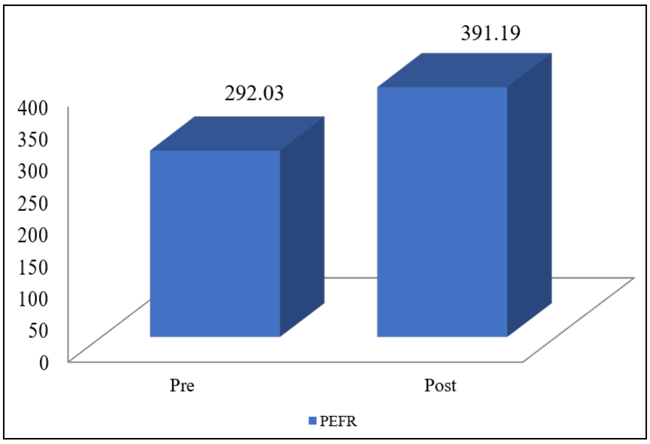


Graph 2: Age distribution

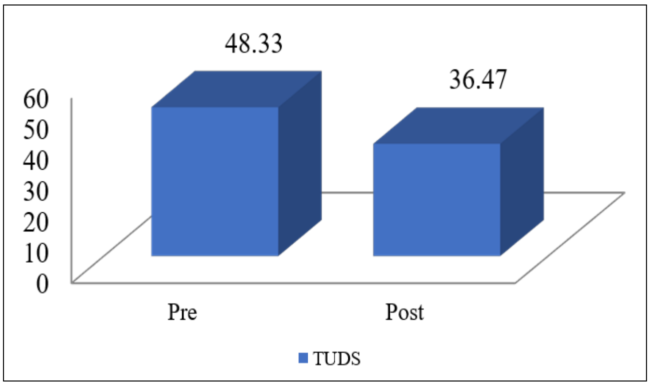
Table 4: Pre post difference within groups

Sl. No.	Variable	Pre	Post	Þ-Value
1	PEFR	292.03±44.52	391.19±54.98	<0.0001
2	TUDS	48.33±5.37	36.47±4.02	<0.0001
3	M-BORG	2.69±0.71	0.14±0.23	<0.0001
4	SIS 3.0	44.22±11.35	57.49±10.71	<0.0001

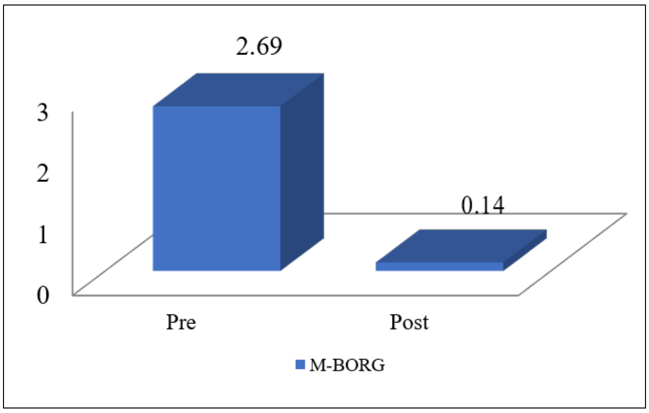
The mean pre PEFR score was 292.03 with standard deviation of 44.52 was improved to post mean PEFR score was 391.19 with standard deviation of 54.98 which was statistically significant (Þ-value < 0.0001). The mean pre TUDS score was 48.33 with standard deviation of 5.37 was improved to post mean TUDS score was 36.47 with standard deviation of 4.02 which was statistically significant (Þ-value < 0.0001). The mean pre M- BORG score was 2.69 with standard deviation of 0.71 was improved to post mean M- BORG score was 0.14 with standard deviation of 0.23 which was statistically significant (Þ-value < 0.0001). The mean pre SIS 3.0 score was 44.22 with standard deviation of 11.35 was improved to post mean SIS 3.0 score was 57.49 with standard deviation of 10.71 which was statistically significant (Þ-value < 0.0001).



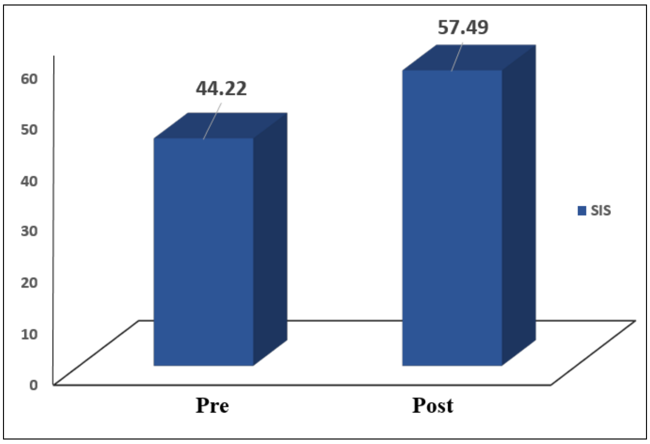
Graph 3: PEFR



Graph 4: TUDS



Graph 5: M-BORG



Graph 6: SIS

Discussion

In stroke, the respiratory function impairment is common in which pneumonia following stroke is the most common respiratory complication. There are many studies that focus on the neurological deficits and its signs and symptoms but the respiratory component is missed out that may result in poor outcomes. So, addressing the respiratory components in stroke is important. Hence, respiratory muscle training has important role in stroke rehabilitation to improve respiratory strength and endurance. So, the present study aimed to Evaluate the effect of respiratory muscle training in the respiratory muscle strength and cardiopulmonary endurance in stairclimbing activities among stroke patients.

The present experimental study was carried out in 36 stroke patients who were selected based on the inclusion criteria. Then, they were given intervention for 6 weeks. Evidences from various articles such as Hyun-Joon Yoo and Sung-Bom Pyun (2018) and Aweto Ha *et al*., (2017) etc were collected to perform the intervention in the study. The effects of the intervention were measured to check the respiratory muscle strength through Peak Expiratory Flow Rate (PEFR), stair climbing activity through Timed Up and Down Stair Test (TUDS), dyspnea through Modified Borg Dyspnea Scale (M-Borg) and quality of life through Stroke Impact Scale 3.0 (SIS 3.0) in stroke patients.

In this study, subjects between 40 to 70 years of age were selected and Age-frequency distribution of patients studied as a Mean of 55.39 and standard deviation of 8.46. Gender-frequency distribution of patients in this study was 26 males that is 72.2% of total sample size and 10 females that is 27.8% of total sample size. In similar study 31 participants with hemiparetic stroke where 17 male, 14 females with mean age 60.4±14.58 years participated in a randomized control trial titled, The effects of dynamic core-postural chain stabilization on respiratory function, fatigue and activities of daily living in subacute stroke patients [33].

To improve cardiopulmonary endurance and activities of daily living, pulmonary function plays an essential role. Zhang X (2020), suggested that post-stroke patients are more likely to suffer from impaired pulmonary function due to long-term hospitalization–induced pulmonary infection. Therefore, it is necessary to provide post-stroke patients with effective pulmonary rehabilitation in their subacute period. It is known that inspiratory muscle strength in people after stroke is less than half of that expected in healthy adults. One of the key disciplines in stroke rehabilitation is inspiratory muscle training which is primarily aimed at restoring and maintaining pulmonary function. Specifically, inspiratory muscle training improves pulmonary function by imposing a resistance to the inspiratory muscles and it may have an additional effect on respiratory muscle endurance which could translate into a more efficient use of the respiratory muscles in activities of daily living [14].

In the current study, the respiratory muscle training was given for 5days/week for 6 weeks with incentive spirometry and diaphragmatic weight training to see its effect on respiratory muscle strength and cardiopulmonary endurance. The similar study was done by Kim CY, Lee JS *et al.*, (2015) where incentive spirometry was used along with abdominal drawing-in manoeuvre for 5days/week for 6 weeks to strengthen the respiratory muscle, which showed significant improvement in respiratory muscle strength post intervention [1].

There are studies which suggests that respiratory muscle function, cardiopulmonary endurance and exercise capacity increases with inspiratory muscle training and one of those studies is a RCT performed by Sutbeyaz ST, Koseoglu F *et al*. (2010), with one group of breathing exercise and the other group of inspiratory muscle training with instrument, given 5 days/week for 6 week suggested that specific inspiratory muscle training in people late after stroke seems to improve respiratory function than general breathing exercises alone.34The article review done by Lui SK and Nguyen MH (2018) suggested that any kind of relevant therapy should be given at least 45 min for 5 days/week, advocated by most of the guidelines [35].

T. Gayathiri and D. Anandhi (2021) studied on the effect of use of incentive spirometry in expiratory muscle strength by using it upside-down and the study concluded the significant improvement in the strength of the expiratory muscles along with inspiratory muscle strength by training with the Incentive spirometry in the upside down and upright positions respectively. In our study also, the similar protocol is used and patients are trained using incentive spirometry in both the sides [36].

There are other studies which was done on diaphragmatic weight training in patients other than stroke i.e., Winser ST (2010) and Sawant AA (2014), such as spinal cord injury and patients weaned from mechanical ventilation respectively, which showed improvement in the strength of diaphragm and pulmonary functions. Thus, the current study was done to see the effect of diaphragmatic weight training in respiratory muscle strength and cardiopulmonary endurance in stroke.

The result of the current study in showed in table IV i.e., comparison of pre and post values of PEFR, TUDS, M-Borg and SIS 3.0 scale within group supported the alternate hypothesis of the study. The result of this study showed highly significant differences within group pre and post treatment. In this study, the mean pre PEFR score was 292.03±44.52 was improved to post mean PEFR score 391.19±54.98 which was statistically significant (Þ-value < 0.0001). In previous study which was done by Kim JH, Park JH (2014), to evaluate the respiratory muscle strength where PEF was one of the outcome measures used, also suggested that there was significant improvement in the post score value for PEFR i.e., 264.00±97.86 to 358.00±98.607 ($p<0.005$) following respiratory muscle training.37 One more study done by Yoo *et al*. (2018) showed significant improvement in FEV1 and PEF following both inspiratory and expiratory muscle training in their study [38].

The result of this study showed significant differences within TUDS group pre and post treatment with mean pre TUDS score 48.33±5.37 to mean post TUDS score 36.47±4.02 which was statistically significant (Þ-value < 0.0001). Zaino CA *et al*. (2004) did the study on children with neurological condition cerebral palsy which suggested that the TUDS is a simple measure of functional mobility that can be easily done in a variety of settings and can be considered for testing and potentially documenting improvement in neurological conditions with suspected limitations in functional mobility and balance.

The result of our study suggested that the mean preM-BORG score was 2.69±0.71 was improved to post mean M-BORG score was 0.14±0.23 which was statistically significant (Þ-value < 0.0001). In the similar study done by De Menezes KK *et al*. (2019), the researcher also concluded that the respiratory muscle training helped to improve strength and dyspnea post stroke ($p<0.01$)39 The current study showed significant improvement in quality of life of stroke patients which was evaluated based on the SIS 3.0 scale i.e. The mean pre-SIS score was 44.22 with standard deviation of 11.35 was improved to post mean SIS score was 57.49 with standard deviation of 10.71 which was statistically significant (Þ-value < 0.0001).

Richardson M *et al*. (2016) in his study concluded that the SIS is a valid and reliable measure of patient functioning post-stroke and is a useful tool for evaluating the effectiveness of stroke rehabilitation interventions in the community setting [26].

The result of the statistical analysis favored the alternate hypothesis with appropriate significance and reinforced that there is significant effect of Respiratory muscle training on respiratory muscle strength and endurance in stroke patients. Hence, alternate hypothesis is accepted and null hypothesis is rejected.

Conclusion

Respiratory muscles have an important role in any kind of rehabilitation program. Following stroke, weakness of the respiratory muscle is common cause to result in poor rehabilitation outcome. It also interferes in the activities of daily living with various signs and symptoms, resulting in poor quality of life. It also results in dyspnea, which is also considered as the major sign for the respiratory weakness. So, to overcome the consequences caused due to respiratory muscle weakness, respiratory muscle training is important. The result of this study suggests that respiratory muscle training not only increases the respiratory muscle strength but also increases the endurance in performing activities of daily living such as climbing up and down the stairs. The result of this study also suggests that it has a very important role in reducing the dyspnea and in improving the quality-of-life post stroke.

Limitations

1. The study was carried out on small sample size.
2. No long term follow up was carried out to assess the carry over effect of the intervention.

Recommendations

- Long-term follow up with large population can be carried out to see the effectiveness of the intervention and it might reveal higher statistical significance.
- Similar study can be performed with randomization of samples in different groups.
- Other pulmonary parameters can be assessed following the same protocol, using different tool, such as FVC, FEV1, FEV1/FVC, VC etc.

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