

## Effect of Ventilatory Facilitation on Chest Expansion And Pulmonary Functions in Children with Spastic Cerebral Palsy

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### Abstract

**Objective:** To find out the effect of ventilatory facilitation on chest expansion and pulmonary functions in children with spastic cerebral palsy.

**Research design:** A single group experimental pre-test post-test study design.

**Participants:** A total of 30 subjects were recruited from the paediatric section of the physiotherapy department of Svnirtar.

**Outcome measures:** chest expansion, PFT, GMFM and TCMS.

**Results and conclusion:** The overall results of this study showed significant improvement in the respiratory parameters: FVC, FEV<sub>1</sub>, PEF, FEF<sub>25-75</sub>, FEV<sub>1</sub>/VC, & MVV, chest expansion and trunk control, measured through TCMS and gross motor functions as measured through GMFM in children with spastic cerebral palsy.

**Keywords:** Cerebral palsy, chest expansion, pulmonary functions, ventilatory facilitation

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### I. Introduction

Cerebral palsy (CP) describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing foetal or infant brain. The motor disorder of CP is often accompanied by disturbances of sensation, perception, cognition, communication, behavior, epilepsy, and secondary musculoskeletal problems. [1] It is a common problem, worldwide incidence being 2 to 2.5 per 1000 live births. [2] Whilst the focus of cerebral palsy is often on movement there is a lot of variety in other symptoms that may be present in a person with CP. Children with CP are at higher risk of breathing problems and suffer from a high incidence of recurrent pneumonia, atelectasis, bronchiectasis, and restrictive lung disease. Illness and premature death occurs most frequently as result of compromised pulmonary function and associated respiratory infections. Respiratory problems play a major role in the life quality and expectancy of these children. Among severely disabled children in three US institutions, 77% of deaths were a result of pneumonia; in a large community survey of children and adults with learning disability, 52% of deaths were caused by respiratory problems. [3, 4]

The condition itself does not directly cause respiratory problems, however the consequences of neuromuscular and musculoskeletal dysfunction indirectly compromise the pulmonary functions. Respiratory muscle weakness occurs as a direct consequence of the underlying pathology. Intercostals are affected relatively early, causing paradoxical breathing and a bell shaped chest. Diaphragm weakness occurs later and heralds the onset of respiratory failure. [5] Hypoventilation tends to occur during sleep first, as weak intercostals become even more hypotonic during REM sleep; respiratory drive is decreased and upper airway obstruction may also occur. Children with spastic cerebral palsy develop chest wall impairments due to many changes in their ribcage and thoracic spine structure overtime. The ribcage tends to stay elevated with lack of effective lower trunk activity to anchor it to the pelvis and begins to take its shape because of muscular action or lack of action.

Breathing by these abnormal patterns for a long period may limit the chest mobility by shortening of respiratory muscles and stiffening of costovertebral joints. [6] Moreover Spinal curvature frequently occurs in CP because of unequal muscle tone and gravity. Chest wall deformity secondary to severe kyphoscoliosis further restricts lung function by decreasing chest wall compliance and decreasing the mechanical advantage of the respiratory muscles. In addition scoliosis can result in unequal lung expansion (basal atelectasis on the concave side and overexpansion of the convex side), leading to ventilation/perfusion mismatch. These factors together increase the work of breathing and predispose to respiratory failure. [7]

Aspiration (Oropharyngeal motor problems), which involves the inhalation of secretions, vomitus, or foreign bodies into the lungs on inspiration, is the major proximate cause of lung injury in CP<sup>14</sup>. Gastro-oesophageal reflux (GOR) appears to be more common, persistent, and severe in children with cerebral palsy.

In CP, muscle weakness, spinal deformity, and consequent restricted chest wall movements result in a

weak cough and ineffective airway clearance. Coughing requires both forceful contraction of expiratory abdominal and intercostal muscles, and precise coordination and timing of expiratory and glottis muscles. An effective cough requires inspiratory muscle strength able to produce an inspiratory volume of 2.3 L or 85–90% of a normal adult total lung capacity. Intact bulbar function is required so that there is then rapid closure of the glottis for 0.2 s, followed by rapid opening of the glottis. This has to be coupled with an abdominal contraction that produces a maximum expiratory pressure >60 cm H<sub>2</sub>O and peak cough expiratory flows of >400 L min<sup>-1</sup>. [8, 9] The cough mechanism is often unsatisfactory in children with CP. The consequences are poor protection of the lower airway when aspiration occurs and inadequate clearance of lower airway secretions, particularly during respiratory infections.

Mary Massery described breathing as an integral part of multisystem interactions and consequences that simultaneously support respiration and posture for all motor tasks. [10] It is the interaction among the diaphragm, intercostals, and abdominal muscles, in addition to support from other trunk muscles, that work together to generate, regulate, and maintain thoracic and abdominal pressures necessary for ongoing, concurrent needs of breathing and motor control of the trunk. [11] Efficient and dynamic respiration is a developmental process inherently related to the development of trunk and postural control. The child with postural difficulty will make functional compensations in an attempt to develop increasingly complex upright posture. It is important to realize that movement related compensations in trunk will have an impact on respiration just as compensation in respiration will have impact on movement. [11]

Children with breathing impairments (primary or secondary in origin) require a variety of interventions to optimize ventilation and oxygen delivery. Various treatment techniques available so far are: Breathing Exercises, Positioning, Manual techniques (chest percussion, vibration, chest-shaking, directed coughing, or forced exhalation technique), Postural drainage, IPPB, Cough assist, Suction, MIE, incentive spirometry. Ventilatory facilitation techniques which involve upper limb, trunk and respiration patterns together, to facilitate other accessory muscles of ventilation can be used for increasing chest wall mobility and improving ventilation. [12] The mechanism of this technique increases the length of the intercostal muscles and therefore helps in performing effective muscle contraction. The techniques of chest mobilization exercises are composed of, lateral stretching, back extension, lateral bending, trunk rotation, etc. This improves the biomechanics of chest movement by enhancing direction of anterior-upward of upper costal and later outward of lower costal movement, including downward of diaphragm directions. Maximal relaxed recoiling of the chest wall helps in achieving effective contraction of each intercostal muscle. Therefore, the technique of chest mobilization exercise helps in chest wall flexibility, respiratory muscle function and ventilatory pumping.

Incentive spirometry used as an adjunct to chest physiotherapy provides the patient with visual feedback of the volume of air inspired during a deep breath and provides a low-level resistive training while minimizing the potential of fatigue to the diaphragm. It enhances lung expansion and inspiratory muscle strength. Finally, increasing chest movement with stronger contraction of respiratory muscles can help in gaining lung volume, breathing control and coughing efficiency, and reducing symptoms by improving aerobic capacity, endurance, functional ability, and quality of life. [13] Research examining the effectiveness of other treatment methods is available that focuses on improving pulmonary functions in children with spastic CP, yet no research has directly evaluated the effect of combined ventilatory movement strategies and incentive spirometry on lung functions and chest expansion, thereby presenting precise and efficient treatment methods. So, the purpose of this study is to evaluate the effectiveness of ventilatory facilitation strategies combined with incentive spirometry in improving pulmonary functions and chest mobility in children with spastic CP.

## **II. Aim**

To evaluate the effect of ventilatory facilitation along with conventional trunk control exercises on respiratory parameters (lung functions and chest mobility) in children with spastic cerebral palsy.

## **III. Methodology**

**Study Design:** A single group experimental pre-test post-test study design.

**Sample Size:** A total of 30 subjects were recruited from the pediatric section of the physiotherapy department of Swami Vivekanand National Institute of Rehabilitation Training and Research according to the inclusion and exclusion criteria.

**Inclusion Criteria:** Children diagnosed with spastic diplegic/quadruplegic cerebral palsy. Both genders, with non-ambulatory group of children able to sit without support and ambulatory group of children able to walk with support, age of children ranged between 6 to 12 years. Cognitive function was normal or near normal and were able to follow commands, children having normal oro-motor function. Children who were able to blow - out the candle at a distance of about 10 cm.

**Exclusion Criteria:** Children with spastic hemiplegia, athetoid or ataxic cerebral palsy, hearing, visual or

speech impairment, other cardio- pulmonary dysfunction or abnormality, recent orthopedic surgical procedure.

#### **IV. Procedure**

30 subjects, boys and girls with age ranging from 6-12 years (mean  $8.87 \pm 1.9$ ), out of which 21 were male and 9 were female, 22 were diplegic and 8 were quadriplegic, 25 were supported walkers and 5 were independent sitters were evaluated, recruited from the Department of Physiotherapy based on fulfillment of inclusion and exclusion criteria after signing the informed consent.

All children underwent an initial baseline assessment of:

a) **Pulmonary Function Testing:** The spirometer is a standardized instrument used for the measuring of respiratory parameters. In this study the computerized spirometer **Minispir** is used. The winspiro PRO is a database for the measurement of spirometry and oximetry testing made with any compatible spirometer. Three recordings were taken, one recording for FVC, FEV1, PEF, FEF25-75, one recording for FEV1/VC, and one recording for MVV.

Child was seated erect in a silent room and was given rest for some time for relaxation before the procedure, and was asked to close the mouth around the mouth piece of the spirometer held by the therapist in the mouth of the child and then the child was asked to inspire deeply and exhale forcefully as fast as possible.

b) **Chest Expansion:** Chest expansion was measured with a cloth tape measure held around the circumference of the chest at two levels. Upper thoracic excursion measurements were taken at the level of the fifth thoracic spinous process and the third intercostal space at the midclavicular line. Lower thoracic excursion measurements were taken at the level of the 10th thoracic spinous process and the xiphoid process, as shown in figure. All children were informed about the examination and were asked to take as deep breath as possible and hold it for initial reading measurement and then asked to exhale as much as possible and hold the position for final reading measurement. The difference between the 2 readings was recorded as chest expansion.

c) **Trunk Control Measurement Scale:** A recent observational scale developed to measure the static as well as dynamic trunk control in spastic cerebral palsy children. Used for all three dimensions i.e. Static Sitting Balance, Dynamic Sitting Balance and Dynamic Reactions (equilibrium reactions).

d) **Gross Motor Function Measure:** A standardized observational instrument, valid and reliable to be used for measuring change in gross motor function abilities in cerebral palsy children. For GMFM used GMFM score sheet (GMFM-88 and GMFM-66 scoring) and measured dimension B (sitting), dimension C (crawling and kneeling), dimension D (standing) and dimension E (walking, running and jumping).

#### **V. Exercise Protocol**

a. **Manual lowering of rib cage:**

- Starting position - Children were made to lie on their back (supine) and were asked to breathe in deeply and exhale fully.
- Procedure - The therapist kept her hands over the anterior and lower 3<sup>rd</sup> of the thorax and applied slight pressure while moving the hands in the caudal and medial direction and at the same time the child is asked to breathe in deeply.

b. **Pectoral Stretching coordinated with breathing (Mobilizing of upper chest):**

- Starting position - Sitting
- Procedure - The child was asked to clasp his/her hands behind the head and the therapist sat behind the child and then horizontally abducted the arms (elongating of pectorals), simultaneously the child was asked to take a deep breath (deep inspiration). The child was then asked to bring the elbows together and bent forward during expiration.

c. **Mobilizing of upper chest and shoulders:**

- Starting position - Sitting
- Procedure - While sitting the child was asked to reach with both arms overhead (180° bilateral shoulder flexion and slight abduction) during inspiration and the bent forward at the hips and reached for the floor during expiration. The therapist sat behind the child and provided assistance by holding both the arms while overhead reaching.

**d. Alternating flexion and extension rotation:**

- Starting position - Sitting
- Procedure - While sitting the child is asked to touch the object (ball or toy), kept slightly behind and in the sideways so, that there is extension as well as rotation in the trunk. Similarly the child was then asked to reach toward the floor on the opposite side; again the object was kept slightly forward and sideways on the opposite side.

**e. Breathing exercises using incentive spirometer:**

- The children were asked to hold the incentive spirometer in upright position (if not possible then assisted by therapist during therapy session and by care taker at home) and the mouth piece was placed in their mouth, making sure the lips were sealed tightly around the mouth piece. They were encouraged to breathe in slowly and as deeply as possible and then hold the breath as long as possible (for at least 3 seconds), and to breathe out forcefully.
- After a rest of few seconds they were asked to repeat the procedure, 10 times/sessions, 4 times a day, for 6 weeks.
- The children were also asked for balloon blowing, taking of thick liquids through a straw at home for carry over effect.

f. In addition to breathing protocol all children underwent the conventional trunk control exercises.

i. In prone position - prone push up

Starting Position - Prone lying with forearm supported

Procedure - The children were asked to raise their head and upper trunk and to look up with forearm supported, and the position for a count of 10. Progression was done by raising upper trunk with hand supported only and then adding unilateral arm lifts and leg lifts.

ii. In supine position - bridging, unilateral bridging and side lying to sit to both sides. All the exercises were performed for a count of 10.

a) Starting Position - Children were asked to lie on their back (supine) with the knees bent and arms above the head.

Procedure - The children were asked to raise their pelvis towards the ceiling, maintaining as neutral spine as possible, holding the position for a count of 10. Progression was done by adding unilateral bridging.

b) Similarly for side lying to sitting the starting position was same but the feet of children were on the floor.

Procedure - The arm was kept in slight abduction and the child was asked to bear weight on the elbow of the abducted arm while rotating to same side to attain sitting and the therapist assisted by holding other arm.

iii. In quadruped position- unilateral arm lifts, unilateral leg lifts, and 'superman position' i.e. alternate arm and leg lifts.

Starting Position - Prone lying

Procedure - Children were asked to attain quadruped position, maintaining spine in neutral position. Progression was done from quadruped to unilateral arm lifts then unilateral leg lifts and later alternate arm-leg lifts (superman position). Progression from quadruped to kneeling was done first supported then keeping extremities by side and later the child was encouraged for overhead elevation of bilateral upper extremities. All exercises were performed for a count of 10 while maintaining as neutral spine as possible.

iv. In kneeling position - overhead arm elevation, half-kneeling, half-kneel to stand.

Starting Position - Quadruped

Procedure - Children were asked to attain kneeling, first with support then without support. Progression was done by adding overhead elevation of bilateral arms, then half kneeling and finally half kneel to stand. The exercises were performed to a count of 10 while maintaining as neutral spine.

v. In sitting position - reaching activities, cross leg sitting, forward and lateral bending.

Starting Position - Sitting at the edge of couch with bilateral feet supported.

Procedure - The children were asked to reach for a toy in all directions (anterior and sideward), attain cross leg sitting, forward and lateral bending and progression was done by performing these activities in high sitting and on the Swiss ball.

Sit to Stand -

Starting Position – 1) Sitting on low couch

## 2) Squatting on floor

**Procedure** - The children were asked to lean forward and downward, ensuring their feet were appropriately positioned and asked to stand with support from the couch and when gained control were made to stand without support. Progression was done by making stand from low couch to stand from floor (first with support then without support).

All children received breathing exercises along with conventional exercises for a period of 6 weeks, 5 day/ week and 40 minutes/session. Breathing exercises included (both inspiratory and expiratory) using incentive spirometer and chest mobilization exercises; Conventional trunk control exercises performed include; bridging, unilateral bridging, prone to quadruped, unilateral arm and leg lifts in quadruped position, reaching activities in sitting, and sit to stand. After completion of intervention of 6 weeks, all participants received a follow up assessment.

## VI. Data Collection

Measurements were taken prior to the beginning of treatment (0 week) and were repeated finally after the completion of treatment protocol (6th week). Subjects were tested on all the dependent variables according to the above time line. The time line depicts the measurement and treatment schedules. Data collected were transcribed onto a data sheet for each subject separately.

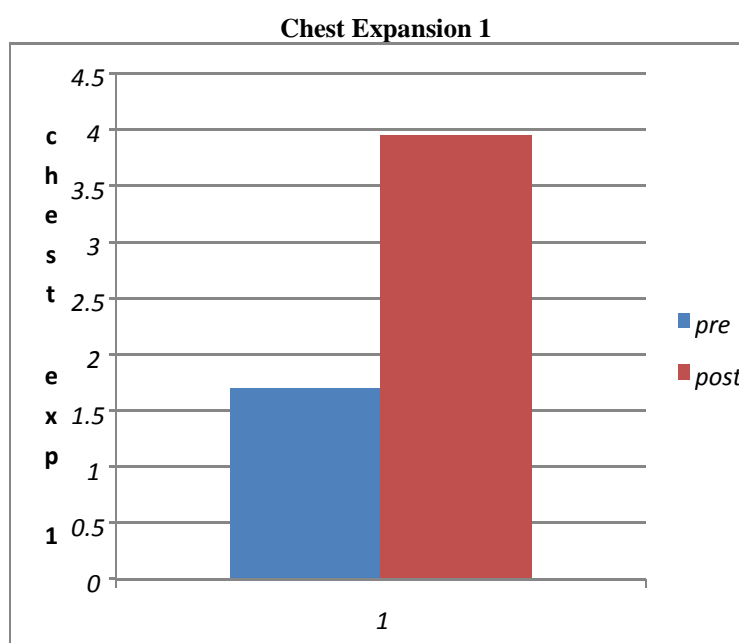
## VII. Data Analysis

The data were analyzed by using the SPSS version 16. Related t - test was used for analysis of within group difference of chest expansion and lung functions. For within group difference for GMFM and TCMS, Wilcoxon Signed Rank test was used. An alpha level of 0.05 was set for analysis.

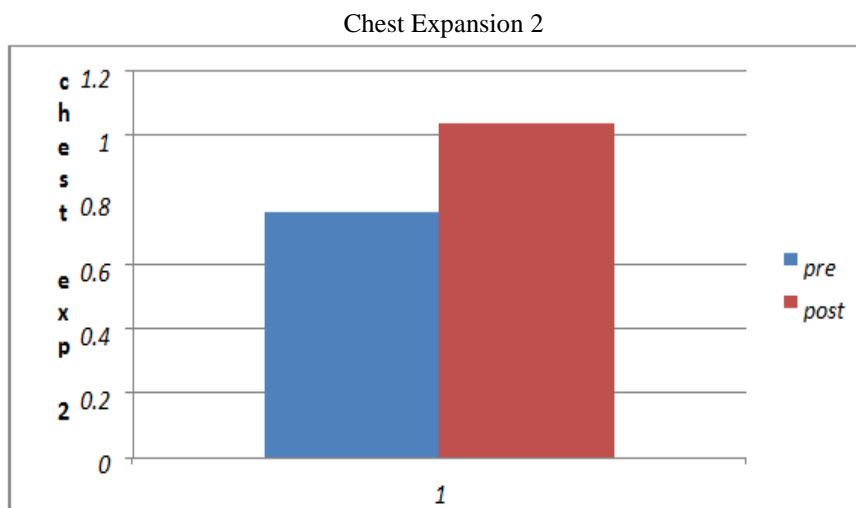
## VIII. Results

### Subject Information

A total number of 30 subjects with mean age of 8.87 (SD± 1.99) years were taken. 70% of subjects was males and 30% of subjects were females.



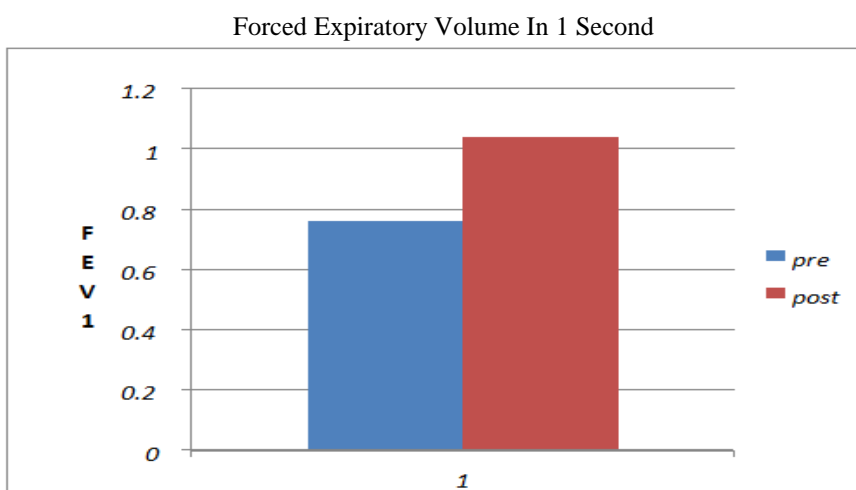
Graph 1 illustrates that there is significant improvement in chest expansion measurement at the second intercostal space from pre to post. Using paired t - test on data for chest expansion,  $t = -12.8$ ,  $df = 29$ ,  $p = .000$ .



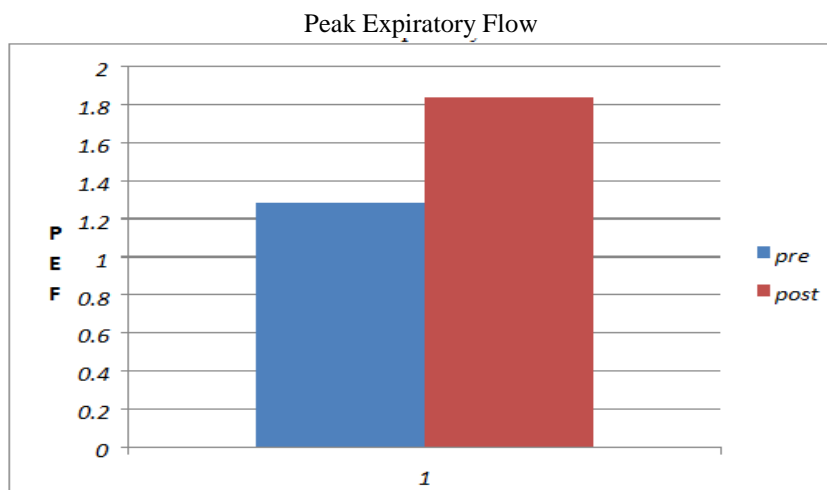
Graph 2 illustrates that there is significant improvement in chest expansion measurement at the xiphoid process from pre to post. Using paired t- test on data for chest expansion,  $t = -11.395$ ,  $df = 29$ ,  $p = .000$ .



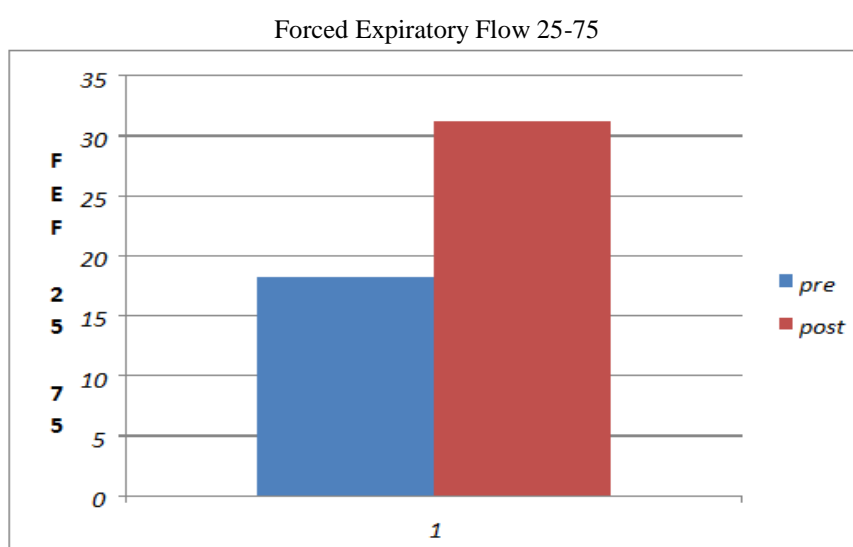
Graph 3 illustrates that there is significant improvement in FVC from pre to post. Using paired t - test on data for FVC,  $t = -5.228$ ,  $df = 29$ ,  $p = .000$ .



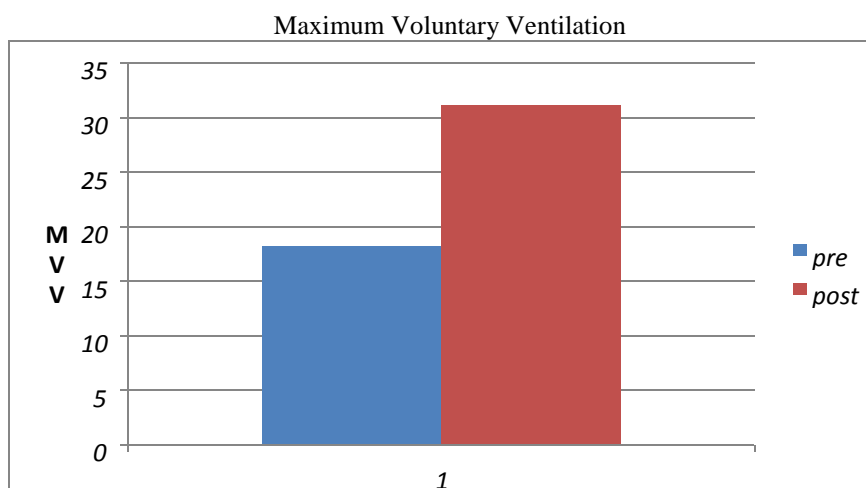
Graph 4 illustrates that there is significant improvement in FEV1 from pre to post. Using paired t - test on data for FEV1,  $t = -6.998$ ,  $df = 29$ ,  $p = .000$ .



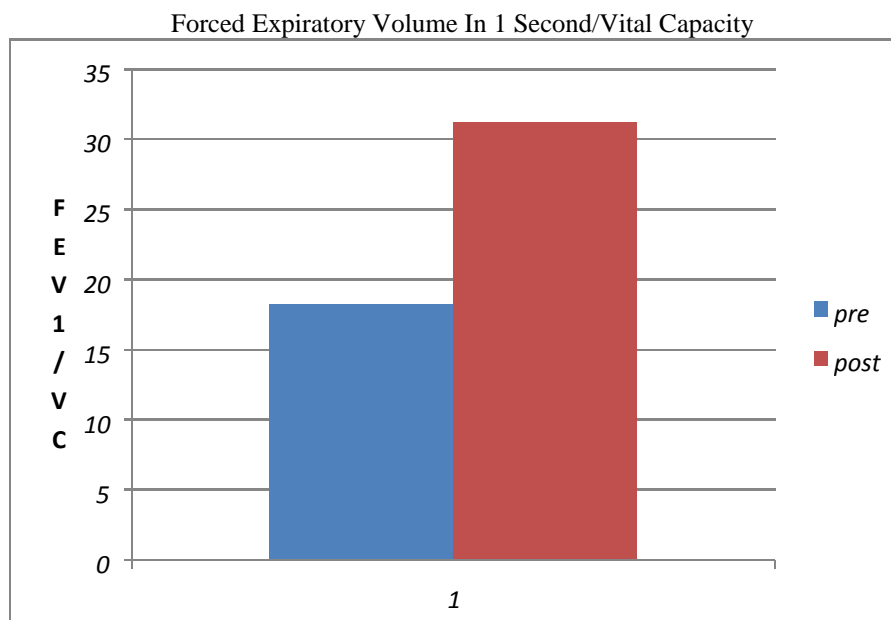
Graph 5 illustrates that there is significant improvement in PEF from pre to post. Using paired t - test on data for PEF,  $t = -5.667$ ,  $df = 29$ ,  $p = .000$ .



Graph 6 illustrates that there is significant improvement in FEF25-75 from pre to post. Using paired t - test on data for FEF25-75,  $t = -5.847$ ,  $df = 29$ ,  $p = .000$ .



Graph 7 illustrates that there is significant improvement in MVV from pre to post. Using paired t - test on data for MVV,  $t = -8.019$ ,  $df = 29$ ,  $p = .000$ .



Graph 8 illustrates that there is significant improvement in FEV1/VC from pre to post. Using paired t - test on data for FEV1/VC,  $t = -5.160$ ,  $df = 29$ ,  $p = .000$

#### Trunk Control Measure Score

Wilcoxon Signed Rank Test for difference in measurement values with time shows significant difference with Z score  $-4.790$  and  $p = .000$ .

#### Gross Motor Function Measure

Wilcoxon Signed Rank Test for difference in measurement values with time shows significant difference with Z score  $-4.786$  and  $p = .000$ .

### IX. Discussion

The overall results of this study showed significant improvement in the respiratory parameters: FVC, FEV1, PEF, FEF25-75, FEV1/VC, & MVV, chest expansion and trunk control, measured by TCMS and gross motor functions as measured by GMFM in children with spastic cerebral palsy.

#### Pulmonary Functions

The results of this study showed that the values of lung functions were significantly increased from pre to post with time: forced vital capacity (FVC), with pre mean = .81L and post mean = 1.05L; forced expiratory volume in one second (FEV1), with pre mean = .76L and post mean = 1.04L; peak expiratory flow rate; peak expiratory flow(PEF), with pre mean = 1.29L/s and post mean = 1.84L/s; forced expiratory flow(FEF25-75), with pre mean = 1.14L/s and post mean = 1.71L/s; maximum voluntary ventilation(MVV) with pre mean = 18.26L/min and post mean = 31.23L/min; FEV1/VC with pre mean = 51.4% and post mean = 77.57%. All these parameters are important in detecting the ventilatory defects (obstructive, restrictive, and mixed). The important parameters which help in detecting the obstructive disorders are: FVC, FEV1, PEF, FEF25-75, and FEV1/VC. While MVV is decreased in both the conditions but more markedly decreased in obstructive defect. From the results of our study most of the CP children fall in the obstructive ventilatory defect category i.e. 83.33% and only 16.67% were having restrictive defect. All these parameters were decreased in most of the CP children as shown by pre-test PFT's and this may be the result of neuromotor disturbance which caused inability to force the thorax back to normal size and/or may be due at least in part to some degree of obstruction of the upper airways because of the incorrect posture of the thorax, neck and head. [14] In coordinated laryngeal opening with diaphragmatic activity may be another possible cause of airway obstruction. Solot CB, Hillman BC et al. found FEV1 to be low in CP patients. [15]

In CP the inability of the respiratory muscles to adequately increase and decrease the volume of the thoracic cavity may result in stiffening of the costovertebral joints, which may also decrease chest expansion. [16] Also the abnormal breathing patterns seen in CP children like shallow breathing (rapid series of low amplitude excursions coupled with low vital capacity), belly breathing (as the diaphragm contracts during



inspiratory excursions abdomen rises excessively) and reversed breathing (the thorax makes inspiratory excursions while the abdomen makes expiratory excursions, or vice versa), for a long period may further limit chest mobility by shortening of respiratory muscles and stiffening of costovertebral joints. [17] Eventually, chest movement is restricted and chest muscles are weakened. As a result, the ability to take a deep breath, to generate expiratory force, and to cough effectively is impaired.

So the treatment was focused on improving chest wall mobility, normal breathing pattern, and strengthening of respiratory as well as trunk muscles by ventilatory movement strategies and incentive spirometry. The ventilatory movement regimen included manual lowering of rib cage, chest mobilisation exercises which include exercises to mobilize upper chest and stretching of pectoralis muscle along with extension-rotation and flexion-rotation. Manual lowering of ribcage in the medial and downward direction while breathe in, work toward maximizing chest wall mobility. [18] Similarly chest mobilization exercises improve mobility of the chest wall, trunk, and shoulder girdles and alternating extension-rotation and flexion-rotation recruit control of the abdominal oblique and intercostals i.e. right external intercostals and left internal intercostals are recruited for left thoracic rotation while left external intercostals and right internal intercostals are recruited for right thoracic rotation. [19, 20]

All these exercises incorporated with deep breathing work toward maximizing chest wall mobility which resulted in improved ventilation (breathing patterns and lung functions). The reason might be that, due to improved chest wall mobility all muscles of ventilation are at mechanical advantage i.e. optimal resting length. The theory of Laplace's law suggests that the length of muscle relates to the maximal force of either diaphragm or intercostal muscles, which affect ventilation in the lung. [21] Previous evidence showed that stretching the anterior deltoid and pectoralis major muscles, including the sternocleidomastoid, scalenes, upper and middle fibers of trapezius, levator scapulae, etc., can increase vital capacity. So, due to ventilatory movement strategies all the muscles of ventilation are facilitated to work at optimal length which further results in increase in the recruitment of fibers and also in the increased strength and endurance of the muscles of ventilation. In addition to this incentive respiratory spirometry was used in which the child inspired as deeply as possible through a small, hand held spirometer that provided visual feedback about whether a target maximum inspiration was reached. [22]

As muscles are made to work at optimal length due to ventilatory facilitation, so sustained maximum inspirations and controlled expirations with the help of incentive spirometer leads to increase in the volume of air inspired. So, the significant improvement in forced expiratory manoeuvre and slow expiratory manoeuvre may be due to increase in the strength of inspiratory muscles (diaphragm and external intercostals) as well as expiratory muscles (abdominals and internal intercostals), however the abdominals play a major role in expiration as well as in inspiration.

The major function of abdominals with respect to ventilation is to assist with forced expiration. The muscle fibers pull the ribs and costocartilage caudally, into a motion of exhalation. By increasing intra-abdominal pressure, the abdominals can push the diaphragm upward into the thoracic cage, increasing both the volume and speed of exhalation. [23] The abdominals play a significant role in inspiration as well. The increased intra-abdominal pressure created by the abdominal muscles during exhalation forces the diaphragm cranially and exerts a passive stretch on the costal fibers of diaphragm. [24] These changes ready the system for an optimal inspiration by optimizing the length-tension relationship of the muscle fibers of the diaphragm. [23] The possible explanation of the improvement in maximum voluntary ventilation (MVV) following breathing exercise may be increase in respiratory muscle efficiency and strength. While, reduction in air trapping, improvement in lung compliance and reduced airway resistance are the possible effects of respiratory muscle training which led to decrease in work of breathing and fatigue level and increase in endurance level of the muscles of ventilation.<sup>109</sup>

Lastly conventional trunk control exercises in addition to ventilatory strategies like bridging; quadruped; sit to stand etc. might be related to further improvement in lung functions by repositioning the trunk and pelvis in biomechanically more advantageous position, improving ventilation. The erect posture allowed more effective respiration, increasing the capacity to move larger volume of gas. [25]

### **Chest Expansion**

In this study there was significant improvement in chest expansion at both the levels i. e. 3<sup>rd</sup> intercostal space and xiphoid process with time. Increase in chest expansion at the 3<sup>rd</sup> intercostal space level from pre (mean = 1.7cm) to post (mean = 3.95cm) was 2.25cm which was significant with time. Increase in chest expansion at the xiphisternal level from pre (mean = 1.62cm) to post (mean = 3.1cm) was 1.48cm which was significant with time. For chest expansion, normal functioning of nervous system, respiratory muscles and costovertebral joints are needed. In children with spastic CP the limited chest mobility may be due to impaired neuromotor control and incoordination, weakness, spasticity and secondary changes in the respiratory muscles. The inability of the respiratory muscles to adequately increase and decrease the volume of the thoracic cavity

may result in the stiffening of the costovertebral joints, which may also decrease chest expansion. Abnormal breathing patterns that are seen because of reduced chest expansion are shallow breathing (rapid series of low amplitude excursions coupled with low vital capacity) and reversed breathing (the thorax makes inspiratory excursions while the abdomen makes expiratory excursions, or vice versa), and breathing by these patterns for a long period may further limit chest mobility by shortening of respiratory muscles and stiffening of costovertebral joints. [26]

The treatment regimen in this study focused mainly on improving chest wall mobility which eventually improves lung functions with time. All ventilatory movement strategies including manual rib lowering, chest mobilization exercises, rotational exercises and incentive spirometry work toward maximizing chest mobility.

#### **Chest mobilization exercise was carried in 2 ways:**

First the child was made to sit in a chair with hands clasped behind the head, have him or her horizontally abduct the arm, elongating the pectoralis major during a deep inspiration. Then the child was instructed to bring the elbows together and bend forward during expiration. Second, in sitting have the child reach with both arms overhead (180° - bilateral shoulder flexion and slight abduction) during inspiration and then bend forward at the hips and reach for the floor during expiration. [19] The pectoralis major muscle can elevate the upper rib cage when the shoulders and the humerus are fixed. The clavicular head of the pectoralis major can be both inspiratory and expiratory in action, depending on the position of the upper extremity. With the humeral insertion of the pectoralis major below the level of clavicle, the muscle is an expiratory muscle, pulling the manubrium and upper ribs down. With the insertion of pectoralis above the level of the clavicle, such as when the arm is raised the muscle becomes inspiratory muscle, pulling the manubrium and upper ribs up and out. [27] Extension-rotation and flexion-rotation recruit the control of the intercostals, as well as abdominal obliques and maintain active upper trunk extension. [18, 20] Kakizaki et al. attributed the increase in chest wall mobility to increased chest wall compliance or increased respiratory muscle power. [28] Incentive spirometry provides the sufficient stretch to the lung tissue for the purpose of lung expansion thereby increases the lung compliance and thus provides the lung with a relatively more space to expand which in turn causes an overall increase in chest wall expansion.

Also the trunk control exercises focusing upon postural muscle development i.e. multitude of muscles like scapular retractors, spinal extensors, abdominals, glutei etc. can bring about an improvement in posture found in children lacking an appropriate trunk control leading to (a) an improved breathing mechanics, (b) decreased chances of aspiration and improved recruitment of accessory muscles for increasing lung capacity (c) better chest wall recruitment for breathing and (d) improving on to diaphragm's mechanical advantage. [29]

#### **Trunk Control Measure Scale**

There was a significant improvement in TCMS from pre to post after an intervention period of 6 weeks. Breathing exercises incorporated with trunk control exercises proved very helpful for trunk control. Massery M et al. described that the trunk of the body is composed of thoracic and abdominal chambers that are dynamically supported by muscle contractions to provide positive pressure in both chambers for respiratory and postural support. The primary muscles involved in this support are the intercostal muscles, which generate and maintain pressure for the thoracic chamber; the abdominal muscles, which generate and maintain pressure for the abdominal chamber, especially the transverse abdominis; the diaphragm, which regulates and uses the pressure in both chambers; and the back extensors, which provide stabilizing forces for the alignment of the spine and articulation with the ribcage. These muscles work synergistically to adjust the pressure in both chambers so that the demands of ventilation and posture are simultaneously met. [29]

Children with CP generally have weak trunk muscles results in both inefficient breathing as well as impaired trunk control. Ventilatory movement strategies (chest mobilization exercises-for accessory muscles, alternating flexion and extension rotation-intercostals and abdominals) and deep inspiratory and controlled expiratory exercises (for all inspiratory expiratory muscles) by the help of incentive spirometry all the trunk muscles are facilitated (already discussed under pulmonary functions and chest mobility) which help in improving both respiration as well as trunk control. In addition to it conventional exercises further help in improving trunk control as well as ventilation.

Massery M et al. proposed that the passive stretching followed by active elongation of the pectorals, sternocleidomastoid, upper trapezius, and rectus abdominis (achieved by alternate upper extremity weight bearing and reaching exercises in prone, quadruped, crawling, controlled prone extension off the ball, etc) would facilitate both postural muscles of trunk causing upper trunk extension as well as open up of thorax to facilitate inspiration. Activities requiring alternating extension rotation and flexion rotation will recruit control of abdominal obliques and maintain active upper trunk extension. Using bubble blowing, whistle toys, and singing are excellent ways of facilitating ventilation during trunk exercises in CP children. [29]

It has been established through surface EMG that there is a preparatory activation of Transversus abdominis and Internal Oblique earlier relative to the contraction of the arm muscle when added respiratory activity is present in these muscles, as a result of inspiratory loading or voluntary expiration below functional residual capacity. [30] This contraction could cause production of intra-abdominal pressure to assist in stabilization of the trunk and to control postural equilibrium disturbed by the movement of the arm. The potential mechanisms for this include an increase in tension of the thoraco lumbar fascia through which Transversus Abdominis attaches to the spine as well as the increase in intra- abdominal pressure itself. To be effective, these mechanisms require contraction of the diaphragm to prevent its passive lengthening and the displacement of abdominal contents. [31] Thus, contraction of diaphragm improves the trunk stabilization, could be one of the reasons for better improvement. [29]

This view is also supported by the soda pop can model of trunk given by Massery M according to whom the roof of the core muscle structures is the diaphragm, and simultaneous contraction of the diaphragm, the pelvic floor muscles, and the abdominal muscles, is required to increase intra-abdominal pressure, providing a more rigid cylinder for trunk support, decreasing the load on the spine muscles and allowing increased trunk stability. The diaphragm contributes to intra-abdominal pressure before the initiation of limb movements, thereby assisting spine/trunk stability. [29] Trunk stabilization exercises in a variety of positions like supine, prone, quadruped, kneeling and sitting recruit the core stabilizer muscles during these exercises, as established by EMG studies performed on normal individuals and low back pain patients. [32, 33] It has been seen that during exercises in supine included bridging and unilateral bridging activities, all back muscles contribute in a similar way to control spine positions and movement in healthy population. [34]

### **Gross Motor Function Measure**

There was significant improvement from pre to post with time. The performance of ventilatory facilitation and trunk stabilization exercises is to improve the trunk control as evident by the improvement in TCMS score with time, so it can be postulated that improved trunk control could be responsible for an improvement in GMFM score. The dimension B i.e. sitting, C i.e. crawling, D i.e. standing and E i.e. walking were used to measure the improvement in function. The dimension B of GMFM requires trunk ability to pull up to sit from lying, ability to maintain static sitting posture, ability to reach a toy in front and side with and without arm propping, ability to maintain unilateral side sitting and ability to assume quadruped from sitting. The dimensions C and D require the child to attain prone on hands, quadruped from prone, weight shifting, unilateral limb lifts in the same position, attain kneeling; standing with support, standing without support etc. The dimension E requires the child to attain standing with or without support, ability to bear weight on one limb at time, propel forward etc. All of these activities require control of the trunk and pelvic segments in space, and require trunk to act as a stable base upon which activities of limbs can be performed.

The improvement in trunk stabilisation by performing trunk exercises leads to (a) improved length tension relationship of the upper and lower limb muscles which originate from the girdles which in turn are linked to spine, (b) improved phasic contraction of spinal muscles, (c) decreased freezing and improved degree of freedom leading to smoother and more appropriate and purposeful movements. [35] Another factor responsible for improvement in GMFM scores could be that the practice of functional activities like reaching in various directions while sitting upright, kneel sitting to kneeling, sit to stand with support, etc. have the potential to train aspects of muscle performance such as coordination, strength, endurance, physical conditioning) as well as motor learning, as all these tasks resembled the items of GMFM scale. [36]

Since these exercises simulated the goal movement and context of movement occurs thus can be transformed as an improvement of performance on GMFM score. [37] In addition, respiratory exercises along with these activities help in achieving better ventilation, whose demand increases physiologically as the child achieves a higher motor development milestone. Adequate respiratory levels are required to sustain a posture and perform function while maintaining it as considerable numbers of studies have demonstrated the respiratory muscles as the limiting factor of physical performance in healthy individuals, athletes, COPD, and in patients with neuromuscular diseases. [38]

## **X. Conclusion**

The results of this study showed that ventilatory movement strategies along with incentive spirometry in addition to conventional exercises were effective in improving respiratory parameters (FVC, FEV1, PEF, FEF25-75, FEV1/VC, MVV, and chest expansion), trunk control and gross motor functions in children with spastic cerebral palsy.

**Limitations:** Small sample size, no control group was taken.

## XI. Clinical Utility

The ventilatory facilitation techniques could be used simultaneously with conventional trunk control exercises in clinic as well as in home based settings to bring about an improvement in respiratory parameters as well as in trunk control in children with CP.

## References

- [1]. Rosenbaum P et al. (2007) A report: the definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol Suppl.* 109: 8 – 14.
- [2]. Jan MM (2006) Cerebral Palsy: Comprehensive Review and Update. *Ann Saudi Med.* 26(2): 123 – 32.
- [3]. Plioplys AV et al. (1998) Survival rates among children with severe neurologic disabilities. *South Med J.* 91(2): 161 – 72.
- [4]. Hollins S et al. (1998) Mortality in people with learning disability: risks, causes, and death certification findings in London. *Dev Med Child Neurol.* 40(1): 50 – 6.
- [5]. Killburn KH et al. (1959) Cardiopulmonary insufficiency in myotonic and progressive muscular dystrophy. *N Engl J Med.* 261: 1089 – 96.
- [6]. Ersöz M et al. (2006) Decreased chest mobility in children with spastic cerebral palsy. *Turk J Pediatr.* 48(4): 344 – 350.
- [7]. Seddon PC, Khan Y (2003) Respiratory problems in children with neurological impairment. *Arch Dis Child.* 88: 75 – 78.
- [8]. Leith DE (1985) The development of cough. *Am Rev Respir Dis.* 131(5): S39 – 42.
- [9]. Leiner GC et al. (1963) Expiratory peak flow rate. Standard values for normal subjects. Use as a clinical test of ventilatory function. *Am Rev Respir Dis.* 88: 644 – 651.
- [10]. Massery M (2006) Multisystem Consequences of Impaired Breathing Mechanics and/or Postural Control; Frownfelter D, Dean E, eds. *Cardiovascular and Pulmonary Physical Therapy Evidence and Practice.* 4<sup>th</sup> edition. Elsevier Health Sciences. Chapter 39.
- [11]. Hodges PW et al. (2001) Postural Activity of the Diaphragm is reduced in Humans When Respiratory Demand Increases. *Journal of Physiology.* 537(3): 999 – 1008.
- [12]. Jennifer A and Prasad SA (2008) Physiotherapy techniques. In: *Physiotherapy for respiratory and cardiac problems*, 4th edition. Churchill Livingstone.
- [13]. Leelarungrayub D (2012) Chest Mobilization Techniques for Improving Ventilation and Gas Exchange in Chronic Lung Disease, *Chronic Obstructive Pulmonary Disease - Current Concepts and Practice*, Dr. Kian- Chung Ong (Ed).
- [14]. Nwaobi OM, Smith PD (1986) Effect of adaptive seating on pulmonary function of children with cerebral palsy. *Dev Med Child Neurol.* 28: 351 – 354.
- [15]. Solot CB (1998) Promoting function: communication and feeding. In: Dormans JP, Pellegrino L (eds). *Caring for Children with Cerebral Palsy.* Baltimore: Paul H. Brookes Publishing Co, 347 – 370.
- [16]. McCool FD, Tzelepis GE (1995) Inspiratory muscle training in the patient with neuromuscular disease. *Phys Ther.* 75(11): 1006 – 14.
- [17]. O'Donnell DM (2000) Pulmonary complications in neuromuscular disease. *Adolesc Med.* 11: 633 – 645.
- [18]. Frownfelter DL, Dean E (2006) *Cardiovascular and pulmonary physical therapy: evidence and practice.* 4<sup>th</sup> edition. Mosby/Elsevier.
- [19]. Kisner C, Colby LA (2007) *Therapeutic exercise: foundations and technique.* 5th edition. FA Davis Company, Philadelphia.
- [20]. Whitelaw WA et al. (1992) Intercostal muscles are used during rotation of the thorax in humans. *J Appl Physiol.* 72(5): 1940 – 44.
- [21]. Grossman M et al. (1982) Review of length-associated changes in muscle. *Physical Therapy.* 62: 1799 – 1808.
- [22]. Crowe JM, Bradley CA (1997) The effectiveness of incentive spirometry with physical therapy for high-risk patients after coronary artery bypass surgery. *Phys Ther.* 77(3): 260 – 8.
- [23]. Starr J, Dalton D, Cynthia C, Pamela K (2005) *Joint Structure and Function.* 4<sup>th</sup> edition. FA Davis Company, 193 – 212.
- [24]. De Troyer A et al. (1981) The diaphragm: Two muscles. *Science.* 213(4504): 237 – 8.
- [25]. Pellegrino R et al. (2005) Interpretative strategies for lung function tests. *The European respiratory journal.* 26(5): 948 – 68.
- [26]. Ersöz M et al. (2006) Decreased chest mobility in children with spastic cerebral palsy. *Turk J Pediatr.* 48: 344 – 50.
- [27]. Levangie PK, Norkin CC (2011) *Joint Structure and Function: A Comprehensive Analysis.* 5<sup>th</sup> edition. FA Davis Company.
- [28]. Kakizaki F et al. (1999) Preliminary Report of the Effects of Respiratory Muscle Stretch Gymnastics on Chest Wall Mobility in Patients with Chronic Obstructive Pulmonary Disease. *Journal of Cardiopulmonary Rehabilitation.* 19(6): 390 – 91.
- [29]. Massery MP (1991) Chest development as a component of normal motor development: implications for pediatric physical therapists. *Pediatric Physical Therapy.* 3: 3 – 8.
- [30]. Hodges PW, Gandevia SC (2000) Changes in intra-abdominal pressure during postural and respiratory activation of the human diaphragm. *Journal of Applied Physiology.* 89(3): 967 – 76.
- [31]. Hodges PW et al. (2002) Coexistence of stability and mobility in postural control: evidence from postural compensation for respiration. *Experimental Brain Research* 144(3): 293 – 302.
- [32]. Erkstorn RA et al. (2007) Electromyographic Analysis of Core Trunk, Hip, and Thigh Muscles during Rehabilitation. *Journal of Orthopaedic Sports Physical Therapy.* 37(12): 754 – 62.
- [33]. Kavcic N et al. (2004) Determining the Stabilization Role of Individual Torso Muscle during Rehabilitation. *Spine.* 29(11): 1254 – 65.
- [34]. Stevens VK et al. (2006) Trunk muscle activity in healthy subjects during bridging stabilization exercises. *BMC Musculoskelet Disord.* 7: 75.
- [35]. Moerchen VA (1994) Respiration and Motor Development: A systems perspective. *Neurology Report.* 18(3).
- [36]. Shumway CA, Wooliacott MH (2001) *Motor Control Theory and Practical Applications.* 2<sup>nd</sup> edition. JB Lippincott. Philadelphia.
- [37]. Lederman E (2010) The Myth of Core Stability. *Journal of Body Work and Movement Therapies.* 14(1): 84 – 98.
- [38]. Boutellier U et al. (1992) The Respiratory System as an Exercise Limiting Factor in Normal Trained Subjects. *European Journal of Applied Physiology.* 65(4): 347 – 353.

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