Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 09, pp.39528-39536, September, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

EFFECT OF VENTILATORY FACILITATION ON IMPROVEMENT OF TRUNK POSTURAL CONTROL IN SPASTIC CEREBRAL PALSY CHILDREN

***Pratiksha Arya, Mrs. Monalisa Pattnaik and Dr. Patitapaban Mohanty**

Swami Vivekanand National Institute of Rehabilitation Training and Research, Olatpur, Bairoi, Cuttack, India

ARTICLE INFO

Article History:
Received 20th June, 2016
Received in revised form
09th July, 2016
Accepted 08th August, 2016
Published online 30th September, 2016

Key words:

Ventilatory facilitation, Trunk control, Cerebral palsy.

ABSTRACT

Objective: To compare the effect of ventilatory facilitation along with trunk control exercises with only trunk control exercises on trunk control in spastic cerebral palsy children.
Research design: Experimental pre-test and post-test study design.
Participants - Thirty children with spastic cerebral palsy were taken from pediatrics Physiotherapy unit of SVNIRTAR, Olatpur, Cuttack, Odisha.
Outcome measures: Chest expansion, GMFM, TCM.
Results and Conclusion: Trunk control exercises incorporated with ventilator facilitation brings about more trunk control, chest expansion and overall function than trunk control exercises only.

Citation: Pratiksha Arya, Mrs. Monalisa Pattnaik and Dr. Patitapaban Mohanty, 2016. "Effect of ventilatory facilitation on improvement of trunk postural control in spastic cerebral palsy children", *International Journal of Current Research*, 8, (09), 39528-39536.

INTRODUCTION

Respiration is a dynamic and interactional component of mobility that should be considered a relevant parameter in motor development. Shared musculoskeletal structures combined with the dynamic pulmonary demands of movement suggest that the role of respiration in motor function is indeed significant. The cardiopulmonary system is unique in this respect i.e. it provides both physiological support (oxygen delivery) as well as a mechanical support (respiratory/trunk muscle control) for movement. Thus, breathing is an integral part of the multisystem interactions and consequences that simultaneously support respiration and postural control for all motor tasks. (1) According to Massery, muscles of respiration are also muscles of postural support and vice versa; thus, every muscle that originates or inserts onto the trunk is both a respiratory and postural muscle. This duality of function means that respiration and postural control can never be evaluated as isolated responses. The soda pop can model seeks to illustrate the dual purpose. (2) Children with severe neurological deficits often show a very different picture of chest development. Frequently, they don't develop adequate upper extremity and neck muscle control, causing their upper chests to retain the more primitive triangular, flattened shape. In some cases the child's diaphragm remains so strong and unbalanced by the abdominal and intercostal muscles that it creates a cavus deformity (pectus excavatum) at the sternum. (2) Most children with severe neuromuscular impairments require significant assistance to maintain an upright posture, so spending more time in recumbent position. In some cases of prolonged supine posturing combined with hyperactivity of the rectus abdominis, as seen with spastic tetraplegic CP, the chest will become flattened anteriorly, yet flared laterally in the lower ribs. Pronounced muscle weakness can produce such severe chest deformities that the child is not able to fulfill his ventilatory needs. Therefore, positioning of the patient and total inhibitory or facilitatory techniques will become a vital importance when developing a treatment plan for maximizing respiratory function. Addressing ventilation and trunk control simultaneously has intuitive appeal based not only on shared musculoskeletal relationships but also on the necessity of pulmonary tolerance for motor activity. No significant experimental studies have been done to compare the effect of ventilation on postural control in CP, except a few single case studies on cystic fibrosis, CVA and SCI patients. Thus, the proposed study emphasizes the use of ventilatory strategies to improve chest development and to find out the postural effects of ventilatory muscle training on trunk postural control in spastic cerebral palsy children.

****Corresponding author: Pratiksha Arya,***
Swami Vivekanand National Institute of Rehabilitation Training and Research, Olatpur, Bairoi, Cuttack, India.

MATERIALS AND METHODS

Study design- A 2 group experimental pre-test and post-test study design.

Sample size- A total of 30 subjects were recruited from the paediatric section of the physiotherapy department of SVNIRTAR according to the inclusion and exclusion criteria.

Sampling- Patients were randomly assigned to 2 different treatment groups after getting consent.

Inclusion criteria- Children diagnosed as spastic diplegic cerebral palsy, aged between 4-10 yrs, children could sit without foot or arm support/ with single arm support for 10 seconds at least, but not able to stand independently, cognitive function normal or near normal, could follow instructions and cooperative, children having normal oromotor function.

Exclusion criteria-Hearing, speech or visual impairment, impaired cognitive function, children with spastic hemiplegic, athetoid, ataxic cerebral palsy, cerebral palsy with mental retardation, children with oromotor dysfunction.

After signing the informed consent by the parents, the children meeting the inclusion ad exclusion criteria were randomly assigned to 2 different treatment groups.
The mean age of children in group 1 was 6 years and there were 8 girls and 7 boys. The mean age of children in group 2 was 5.73 years and there were 10 girls and 5 boys.

Group 1 (Experimental): Ventilatory facilitation and trunk control eercises
Group 2 (Control): Conventional trunk control exercises

All participants underwent an initial baseline assessment of chest expansion at 2nd and 9th rib levels, measured by measuring tape, gross motor function measure (GMFM) and trunk control measurement scale (TCMS). Both groups received conventional trunk control exercises. The experimental group in addition, received breathing exercises simultaneously with the conventional exercises in all the positions. The intervention period was of 6 weeks duration, 5days/week, 40 minutes/session. After completion of 6 weeks, all participants received a follow up assessment.

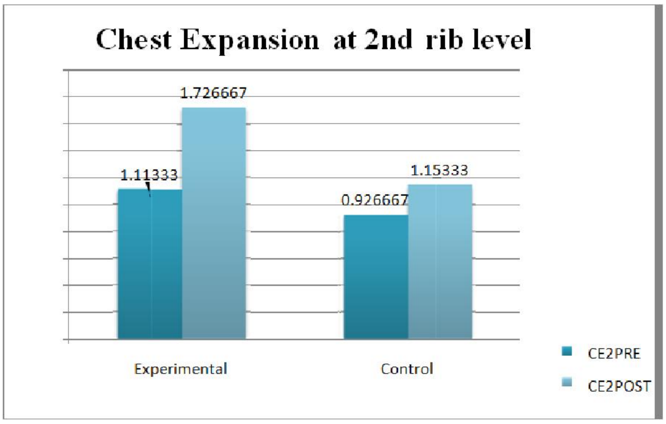
Data analysis

Data was analyzed using 2X2 ANOVA with one between factor (group) with two levels and one within factor (time) with two levels for chest expansion at 2nd and 9th rib level. Between groups difference for GMFM and TCMS was done by Mann Whitney U test and within group difference analysis was done using Wilcoxon Signed Rank test. An alpha level of 0.05 of significance was set. Analysis was performed using SPSS package 16 version.

RESULTS

The graph 1 and 2 show that there has been an increase in chest expansion at both 2nd and 9th rib levels in both experimental as well as control groups, with improvement in experimental group being significantly more than control group.

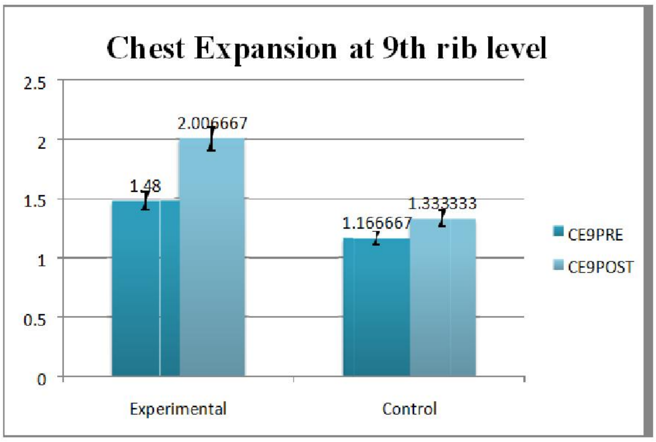
Chest expansion



Graph – 1

2nd Rib level

2X2 ANOVA analysis for chest expansion at 2nd rib level reveals that there was main effect for time as $F_{(1,28,0.05)}=50.908$ and p=0.000. There was a significant effect for group as $F_{(1,28,0.05)} = 3.296$ and p= 0.05. There was a significant effect for time x group as $F_{(1,28,0.05)} = 10.802$ and p= 0.003. Tukey's HSD analysis revealed that the experimental group improved to a greater extent when compared to the control group from pre test to post test.

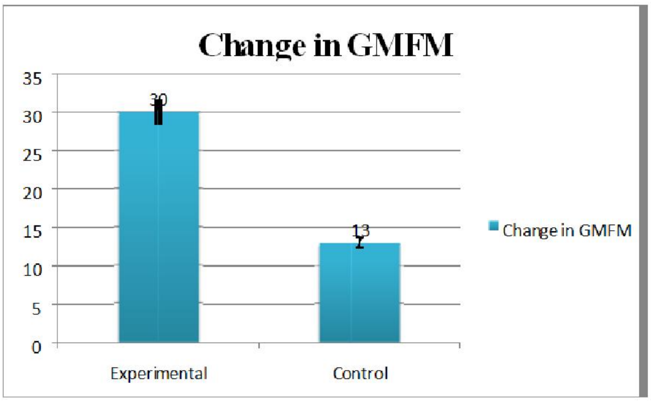


Graph – 2

2X2 ANOVA analysis for chest expansion at 9th rib level reveals that there was main effect for time as $F_{(1,28,0.05)} =29.494$ and p=0.000. There was a significant effect for group as $F_{(1,28,0.05} = 4.824$ and p= 0.037. There was a significant effect for time x group as $F_{(1,28,0.05)} = 7.952$ and p= 0.009. Tukey's HSD analysis revealed that the experimental group improved to a greater extent when compared to the control group from pre test to post test.

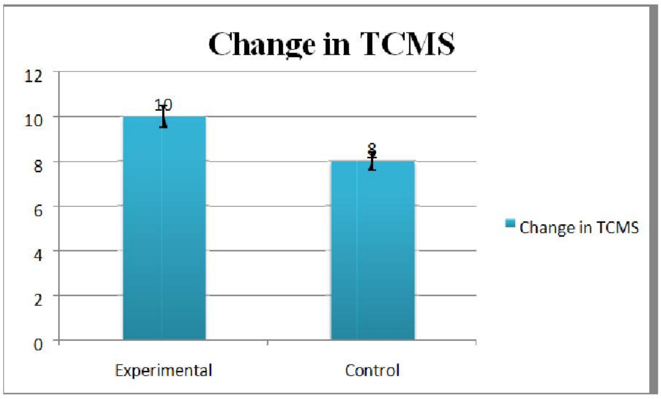
The graph 3 shows there was a significant change in both the groups with intervention, with experimental group showing significantly more change as compared to the control group. Mann whitney U test showed that Z score is -3.635, value of test is 25.00 with $p<0.000$ indicating a significant difference in change of scores between groups.

GMFM



Graph – 3

TCMS



Graph – 4

The graph 4 shows there was a significant change in both the groups with intervention, with experimental group showing significantly more change as compared to the control group. Mann whitney U test showed that Z score is -2.209, value of test is 59.5 with $p<0.027$ indicating a significant difference in change of scores between groups.

DISCUSSION

Overall results of the study show that after 6 weeks of intervention on spastic cerebral palsy children, both the groups showed significant improvement in chest expansion. However the experimental group who were given breathing exercises along with trunk stabilization exercises showed significantly better improvement than control group who were given only trunk stabilization exercises. Improvement in chest expansion occurred more at the 2nd rib level in comparison to the 9th rib level in both the groups. No improvement in chest expansion at 9th rib level was seen in control group. Trunk control as measured through trunk control measurement scale (TCMS) was improved significantly in both the groups of children with improvement occurring more in the experimental group who were treated with trunk and breathing exercises simultaneously. Improvement in function was measured using gross motor function measure (GMFM) in three dimensions i.e. sitting, crawling and kneeling and standing; in which both groups have improved significantly with time and experimental group showing more improvement as compared to the control group.

Chest expansion

Increase in chest expansion at 2nd rib level was 55.09% and 24.46% for experimental and control group respectively which was significant with time. Increase in chest expansion at 9th rib level was 35.5% for experimental group and was significant with time, whereas for control group it was 14.29% which was not significant with time. The prime factor for improvement in the chest expansion in the control group could be an increased biomechanical advantage for functioning of the respiratory muscles as a result of improved upright posture. Murat Ersoz *et al* has pointed out that in neuromuscular diseases, a chronically slumped posture, the result of collapsing forces, can cause a multitude of postural deficiencies including: 1) a thoraco-lumbar kypho-scoliosis which compresses the anterior rib cage, often causing a mid trunk fold at the xiphoid process, thus restricting breathing mechanics, 2) a compensatory forward head position on top of the thoracic kyphosis which compromises swallowing mechanics thereby increasing the risk of aspiration and mechanically compromising the recruitment of accessory muscles for increased lung volumes, 3) a compensatory upper quadrant position including protracted scapula and humeral internal rotation, impairing shoulder mechanics as well as chest wall muscle recruitment for breathing, and 4) a posterior pelvic tilt with excessive hip external rotation thus further compressing forces at the mid trunk and pelvic floor further impairing the diaphragm's mechanical advantage. (4,5) Therefore, as Massery mentioned, exercises focusing upon postural muscle development, i.e. a multitude of muscles like scapular retractors, spinal extensors, abdominals, glutei, etc., which were administered to both the groups can bring about an improvement in posture found in children lacking 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 onto diaphragm's mechanical advantage. (6) The important role of abdominal muscles in establishing effective ventilation can be explained biomechanically as at the end of expiration diaphragm is forced upward, thus stretching it to an optimal length tension relationship. As a consequence muscle is more prepared to initiate a more forceful contraction at the next inspiratory cycle. Also upright positioning along with growing abdominal muscles pulls and rotates the ribs especially lower ribs downwards, widening the intercostals spacing and therefore achieving an ideal position for intercostals function in inhalation and exhalation maneuver. Specifically, the intercostals can now function to (a) stabilize the chest wall during the negative thoracic pressure created during inhalation, (b) increase the lateral and anterior dimensions of the chest wall during inhalation, and (c) compress the chest wall during forceful exhalation. (7,8) Thus, an improvement in abdominal muscle activation as a result of trunk stabilization exercises improves the biomechanical advantage for better activation and functioning of the respiratory muscles leading to an improvement in chest expansion. In addition to decreased activation of respiratory muscles, another negative effect of slumped posture is the decreased lung volume, probably due to increased crowding of ribs anteriorly and increased thoracolumbar kyphosis posteriorly. Landers has shown that a collapsed posture (slumped) results in a decrease in ventilation and lower lung volumes in healthy adults. (9) Lin evaluated pulmonary values in 3 sitting postures and 1 standing posture for 70 normal adults. (10) The subject's posture and lumbar lordosis significantly affected lung volume (spirometric values): standing had the greatest lumbar lordosis and the highest pulmonary values, whereas slumped sitting had the least lumbar lordosis and the lowest lung volumes. He has also reported that an approximately 50% increase in FEV1% vital capacity values could be obtained with an adaptive seating system which corrected the posture of the thorax and head. These changes were attributed to the unobstructed airway obtained by this system. Similarly, an improved upright posture could have increased the lung volume and pulmonary capacity which reflected as increased chest expansion in our study. Another factor responsible for increased chest expansion could be understood from the fact that all the muscles originating or inserting on the trunk act as both the muscles of ventilation as well as the muscles of trunk control. (11) In neuromuscular diseases, if CNS drive directs to focus on ventilation at the expense of postural control, trunk is left with inadequate ability to generate and regulate positive pressure adequately to meet the needs of the increased postural demand of that activity. This conflict is demonstrated by: (1) over-recruitment of the accessory muscles rather than the diaphragm for ventilation; and (2) over-recruitment of lumbar extensors rather than abdominals, diaphragm and internal intercostals for postural control, leaving the lumbar spine without adequate positive pressure stabilization. But improvement of the ability of the postural muscles to meet the needs of postural control offloads the respiratory muscles especially diaphragm of this extra responsibility and focus on respiratory function. This phenomenon may have increased the chest expansion in the control group. Another hypothesis for improvement in chest expansion occurring with postural exercises can be that strength training of non respiratory muscles can also give a training stimulus to respiratory muscles especially diaphragm as it has been seen that by performing biceps curls and sit-ups four times weekly resulted in significant increases in PImax after 8 weeks of training and further increases at 16 weeks. The finding that PImax was also increased suggests that these maneuvers not only strengthened the muscles of the rib cage but also provided a sufficient strength-training stimulus to the diaphragm. This can occur due to anticipatory contraction of core muscles of the body, whose part is diaphragm also, in preparation to any limb activity, thus giving them a simultaneous strengthening effect. (12) In the experimental group, an improvement in chest expansion could have occurred due to various factors, prime factor being strengthening of the muscles of inspiration and expiration. This effect is supported by the study by Rothman JG, who saw the effect of respiratory exercises on vital capacity of cerebral palsy children which increased by 0.46 liters after exercising for five to seven minutes each day for a period of eight weeks. The mean increase of the vital capacity was 31%. (13) The breathing exercises emphasized strengthening of the muscles of inspiration and the muscles of expiration. The better improvement in chest expansion (45.3%) in experimental group of our study could be due to the added advantage of postural exercises along with breathing exercises.

Mei-Yun Liaw performed resistive inspiratory muscle training (RIMT) in patients with acute complete cervical cord injury for 6 weeks and found, most of the pulmonary parameters - total lung capacity, total lung capacity predicted percentage, vital capacity, minute ventilation, forced expiratory volume in 1 second predicted percentage, chest expansion showed statistically significant improvements within the RIMT and control groups, but the improvements were greater in the RIMT group showing that 6 weeks resistive training can have a strengthening effect on inspiratory muscles. (14) Similarly, in our study also subjects showed improvement in respiratory parameters after 6 weeks of training.

Rik Gosselink gave respiratory muscle training in Severely Disabled Multiple Sclerosis Patients for 8 weeks and concluded that expiratory muscle training tended to enhance both inspiratory and expiratory muscle strength and significantly improved the objectively and subjectively rated cough efficacy, which lasted for 3 months after training cessation. (15) Explanation for the improved inspiratory muscle strength in their study was considered as a result of reduction in residual volume (RV). Expiratory muscle training might have reduced expiratory lung volume, thus allowing the inspiratory muscles to operate at a more advantageous part of the length-tension relationship. Another explanation could be that during expiratory loading, in the absence of sufficient expiratory muscle strength, patients increase their inspiratory lung volume and hence elastic recoil pressure to overcome the expiratory pressure. This stimulus, if high enough can cause a training response of inspiratory muscles. (15) Similar phenomena could be expected in our study as the breathing exercises were primarily encouraged using toys predominating expiratory maneuvers like blowing bubbles, whistles, etc. Also, a decrease in the residual volume (RV) in lung would decrease the tendency of barreling of chest, allowing appropriate recoil of chest wall, thus improving the elastic potential of the chest wall and therefore the chest expansion in our subjects. Another hypothesis with regard to increased chest expansion could be that chest expansion exercises, which include maximum inspiration and expiration, prevent stiffening of costovertebral joints and shortening of respiratory musculature, thus allowing for more expansion to take place. As compared to the 9th rib level, chest expansion improved significantly more at the 2nd rib level, probably due to a greater scope of improvement at that level. This has been proved by previous authors Eunsook park in children with SMA and severe CP with long-term inability to take a deep breath, that they have a low upper to lower chest diameter ratio compared with normally developed children, suggesting chronic hypoventilation of the upper thoracic compartment in children with CP. (16) This shows that though there is a decreased overall ventilation in CP children as compared to controls, there is a comparatively greater scope for improvement in the upper thoracic region as compared to the lower chest region, thus, supporting our hypothesis. The increase in chest expansion at the 9th rib level was not significant in the control group probably due to a lesser development of the abdominal muscles, which biomechanically aid in increasing chest expansion as with the lower ribs stabilized by the oblique abdominal muscles, the initial contraction of the diaphragm lowers and flattens its dome. This piston action increases the vertical diameter of the thorax as it simultaneously decreases the vertical diameter of abdomen, increasing the intra abdominal pressure. This pressure causes the lower ribs to expand laterally. The natural resistance provided by the abdomen stabilizes the dome of the diaphragm, allowing contraction of the costal part of the muscle to elevate the ribs. (17) A lesser improvement in abdominal muscles in control group could have lead to a lesser stabilizing effect on lower ribs and central tendon of diaphragm, thus preventing adequate expansion at the 9th rib level.

Trunk control measurement scale

The present study shows a significant median rank improvement of 10 and 8 in experimental and control groups respectively with experimental group showing significantly better performance on TCMS score. The improvement in TCMS score in control group can be attributed to the performance of trunk control exercises in a variety of positions i.e. supine, prone, quadruped, kneeling and sitting, which could have improved core muscle recruitment. As previous studies by Massery have established that in cerebral palsy children weakness of the trunk muscles i.e. external and internal obliques, spinal extensors, latissimus dorsi, scapular retractors etc occurs; which are important part of core stability of the trunk. (18) This core stability is needed to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated kinetic chain activities. (19) Thus, one factor responsible for improvement in TCMS scores in the control group performing trunk stabilization exercises in a variety of positions like, supine, prone, quadruped, kneeling and sitting could be recruitment of the core stabilizer muscles during these exercises, as established by EMG studies performed on normal individuals and low back pain patients. (20, 21) Performance of core stabilization exercises in various positions which involved supine, prone, sitting and standing and rotations in all positions could have given an opportunity to CP children to develop the movement transitions in these positions which they normally lack. (22) As these exercises included attainment of posture with spinal alignment as neutral as possible, followed by lateral and anteroposterior weight shifts and finally reaching in all 3 planes and transitions between various postures; these could have helped develop trunk control measured through the 3 subscales of TCMS i.e. static- evaluating static trunk control during movement of upper and lower limb; selective movement control- selective trunk movements in 3 planes within base of support; and dynamic reaching- requiring active trunk movements beyond the base of support. (23)

Since the TCMS items measured all 3 aspects of postural control (24) i.e.

a) Proactive or postural orientation, which anticipates the appropriate relationship between body segments in a task specific context. It appears that the control of orientation and the control of balance both require the trunk as an initial reference frame. (25)
b) Postural stability or steady state balance, which is the ability to maintain the COM within the limits of BOS. Loss of recruitment order of muscles and inability to use appropriate postural responses for balance control due to mechanical constraints from reduced cervicothoracic, thoracolumbar and lumbopelvic mobility secondary to factors like spasticity, changes in muscle properties, changes in muscle adaptability, stiffness and abnormal force production hinder the cerebral palsy children to have appropriate postural stability. (26, 27, 28, 29, 30, 31, 32)
c) Reactive postural adjustments or equilibrium reactions, which are flexible and varied responses to perturbations from the environment, self initiated movements, or a moving support surface**,** these reactions are generally too large in cerebral palsy children creating still another balance problem. (33)

Since anticipatory control (production of forces prior to the intended movement) that are crucial to setting the posture to maintain the body upright against the force of gravity while allowing tasks to be accomplished in an efficient, coordinated manner within an environmental context, is imperative for postural control; an improvement in core stability could have ultimately led to improvement in postural alignment. (34) Emphasis on maintenance of appropriate spinal alignment could have decreased stiffness, maintained appropriate postural tone and improved the readiness of muscles to change from static posture to flexible movement. (22) Stretching exercises along with movements in all three planes, combining flexion, extension and rotation through a wide variety of positions to accomplish movement goals, may have improved the temporal coordination between eye, head and limb movements, causing a flexible coupling adapting to the nature of task. (22) Exercises in supine included bridging and unilateral bridging activities. It has been seen that during these exercises, all back muscles contribute in a similar way to control spine positions and movements in healthy population. Veerle K Stevens has supported the above mentioned view by studying the relative muscle activity and the ratios of the back muscles in 3 bridging exercises (single bridging, ball bridge and unilateral bridging), demonstrating similar activity levels for all back muscles, resulting in ratios about 1. (35) In prone position exercises like coming prone on hands, followed by alternating arm lifts and alternating leg lifts were used. Performing exercises in this position may have provided a stretch to the anterior chest wall and stabilized lower ribs, thus providing the abdominal wall muscles (rectus abdominis, external and internal obliques) better length tension relationship. Also the diaphragm over activity is reduced in this position so that other accessory muscles of ventilation, like scapular retractors start functioning which is also primary trunk stabilization muscles. (36) When progressed with upper and lower extremity lifts to challenge the core stabilizers, they help in strengthening the lumbar extensors and gluteal muscles and provide a direct challenge to the anterior stabilizing muscles to hold the pelvis from posterior tilting. (37) The exercises done in quadruped position were: attaining quadruped position, alternating arm and leg lifts, achieving superman position i.e. simultaneous lifting of contralateral arm and back followed by reaching in all 3 planes. This position offers lesser external support than supine and prone and is used as a progression for core stabilisation. (37) These exercises in quadruped position increase the activity of contralateral internal oblique and ipsilateral external oblique. The contralateral internal oblique activate to maintain a neutral pelvic and spinal posture, in effect balancing the internal moments and lateral shear forces; but it occurs in association with ipsilateral external oblique activity so as to make trunk a stable unit. (38, 39) The progression of exercises was done by addition of an unstable base i.e. swiss ball, as it increases the recruitment of abdominal stabilizer musculature. Gregory J Lehman and Behm DG 2005 have advocated the use of unstable bases as the most effective means for trunk strengthening predominantly external oblique and rectus abdominis. (40, 41) In kneeling; attaining, maintaining and coming back to kneel sitting from kneeling was practiced. Progression was done by adding onto bilateral arm lifting. This position is important as it integrates contraction of hip muscles esp. gluteus maximus along with trunk in an antigravity and more functional and developmental position. (42) Bilateral arm lifting elevates the centre of gravity and adds the challenge on core stabilizing muscles.

Finally, the exercises that were performed in sitting position were: sitting straight without support, lifting both arms up, cross legged sitting, leaning in anterior, posterior and lateral directions and reaching in all three planes. These exercises were done to simulate the motor control tasks in TCMS as ideal neuromuscular organisation to movement occurs when the movement is in similar patterns to the goal movement and practiced in context of the particular movement. (43) Thus the core muscles which were trained during the previous positions get an opportunity to activate in a functional task. To address true learning and endurance, each exercise was performed for at least 2 minutes each. (37) A variety of spinal stabilization exercises on mat (stable surface) and swiss ball (labile surface) while transitioning from attaining, maintaining, weight shifting, thus altering the goal were performed as learning retention can be promoted by varying the environment of an activity and changing the order in which activities are performed. (44) Thus an improvement in TCMS scores can be attributed to the increased stabilization effect of core muscles during sitting as these muscles were challenged in the therapeutic exercise programme and led to their conditioning. Improvement in motor behaviour towards expected perturbations can be postulated as another factor bringing about improvement in TCMS scores. Cerebral Palsy children lack the ability to distribute the load i.e. body weight appropriately during static balance and transfer the body weight adequately from one supporting limb to another during dynamic balance tasks. (45) Also evidence exists regarding delayed trunk muscle recruitment with predictable and non-predictable challenges to spinal stability in chronic low back pain patients. (46, 47, 48) Muthukrishnan *et al* has shown an improvement in postural control parameters with core stabilization training in low back pain subjects probably due to the efficient changes related to load transfer and weight distribution patterns of core instability patients. (49) Similar effects of core stabilization exercises could have brought about improvement in TCMS scores in our Cerebral Palsy children. There was a significantly greater improvement in TCMS scores in experimental group to whom breathing exercises were given in addition to trunk postural control exercises. Facilitation of the core stabilizers due to concurrent respiratory activity can be postulated as the prime reason bringing about more improvement in trunk control in the experimental group.

It has been established through surface EMG that there is a preparatory activation of Transverse abdominis and Internal Oblique earlier relative to the contraction of the arm muscles when added respiratory activity is present in these muscles, as a result of inspiratory loading or voluntary expiration below FRC. (50) This contraction could cause production of intra-abdominal pressure to assist in the 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 thoracolumbar fascia through which Transversus Abdominis attached to the spine as well as the increase in intra-abdominal pressure itself. (19) To be effective, these mechanisms require contraction of the diaphragm to prevent its passive lengthening and the displacement of the abdominal contents. (50) Thus, contraction of diaphragm improves the trunk stabilization, could be one of the reasons for better improvement of trunk control in the group receiving breathing exercises along with trunk control exercises. This view is also supported by the soda pop can model of trunk given by Massery 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. (51, 52) The diaphragm contributes to intra-abdominal pressure before the initiation of limb movements, thereby assisting spine/trunk stability. Important part of a core strengthening program as the diaphragm serves as the roof of the core, imparting stability to the lumbar spine by contracting and increasing intra-abdominal pressure. (53) The results of the study by Correˆa and Be´rzin evidenced a significant decrease on the EMG activity of accessory muscles of respiration after treatment with postural as well as breathing exercises on swiss ball in children with mouth breathing syndrome as a result of a better postural alignment, and an adequate respiratory pattern with less participation of inspiratory accessory muscles obtained with the treatment. (54) A similar phenomenon could be responsible for a better trunk control in our patients who received both postural and breathing exercises simultaneously as adequate demands were placed on the respiratory muscles which could work more efficiently with an adequate trunk alignment. Thus increased respiratory demands and improved respiratory patterns could be indirectly facilitating a better trunk control.

Gross motor function measure

The experimental and control group showed an improvement of 30 and 13 ranks respectively which was significant with time. The improvement in experimental group was significantly more than the control group. The performance of core stabilization exercises to improve the trunk control as evident by the improvement in TCMS scores 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 and D i.e. standing were used to measure the improvement in function. The dimension B of GMFM requires trunk ability to pull up to sit from lying, ability of trunk 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 dimension 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.

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 fact is supported by Laurie Snider, showing a level 2a evidence for effectiveness of hippotherapy for treating trunk and hip muscle asymmetry and therefore leading to a better gross motor function. Thus improved trunk control could be one factor which improved GMFM. (55) The improvement in trunk stabilization 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. (1) The trunk exercises were progressed by addition of upper and lower limb movements which could have caused strengthening of trunk and limb muscles while body weight acting as resistance. The free exercises have been postulated in the literature to benefit in strength gain by following few mechanisms: physiologically, improving the efficiency of neuromuscular coordination by reducing state of wasteful tension in muscle, promoting full ROM for the joint which are limited due to spasticity, increase the power and endurance of working muscle by constantly working against body weight, improving the coordination by repetition of exercises, which further simplifies the movement, enhancing the function of trained parts by continuous brain mapping, and by adding in improved self-concept of children. (56, 57) Strength and function are directly proportional to each other as evident by previous studies, Ross Sandy *et al* studied relationship between strength, spasticity, GMFM and gait and found that gait function and GMFM are directly related to strength. Similar results were found by Scholtes VA *et al.* who observed an improvement in standing (Dimension D) and walking and running (Dimension E) of GMFM in CP children after giving exercises like bridging, sit to stand, etc. (58, 59) 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 of these tasks resembled the items of GMFM scale. Since the exercises simulated the goal movement and context of movement, neuromuscular organization to movement occurs. (24, 43) Thus, this can be transformed as an improved performance on GMFM score. Experimental group has shown a significantly better improvement in function than control group, possibly due to addition of respiratory exercises along with these activities helps in achieving a 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 number 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. (60, 61) Persegol L has shown that respiration and locomotion are coupled and neurogenic adaptation occurs in adults in response to physical effort of sustaining gait at a particular speed. (62) Verschuren 2007 reported that administration of physical activity in form of circuit training: aerobic as well as anaerobic, improved the GMFM (Dimension D and E) scores in cerebral palsy adolescents, the changes attributed to improved aerobic capacity, anaerobic capacity and strength in these children. (63) Thus, improved ventilation could also be in part responsible for better GMFM scores in our experimental group. Also, integration of respiration with trunk exercises re-educates optimal neuromuscular strategies to children so that they are better able to use their primary muscles of trunk stabilization i.e. scapular retractors, oblique's, gluteus maximus for trunk stability and minimize the use of secondary muscles like diaphragm for postural stabilization.

Conclusion

Trunk control exercises incorporated with ventilatory facilitation brings about more trunk control, chest expansion and overall function than trunk control exercises only.

Limitations

1. Study sample was small.
2. Study duration of 6 weeks was a small to appreciate any significant changes in the chest wall structure.
3. Carry over effect of the study has not been studied.
4. Spirometer could not be used to measure respiratory parameters.

Clinical utility

The breathing and trunk exercises can be used simultaneously in clinical as well as home based settings to bring about an improvement in trunk control as well as respiratory parameters.

REFERENCES

1. Moerchen VA 1994. Respiration and motor development: A systems perspective. *Neurology Report,* 18(3).
2. Massery MP 1991. Chest development as a component of normal motor development: implications for paediatric physical therapists. *Paediatric Physical Therapy*, 3: 3-8.
3. Bockenhauer SE, Haifan C, Julliard KN *et al*. 2007. Measuring Thoracic Excursion: Reliability of the Cloth Tape Measure Technique. *Journal of American Osteopathic Association,* 107(5).
4. Ersoz M, Selçuk B, Gunduz R, Kurtaran A, Akyuz M 2006. Decreased chest mobility in children with spastic cerebral palsy. *Turk J Pediatr*., 48: 344-350.
5. Massery M, Cahalin L. 2004. Physical Therapy Associated with Ventilatory Pump Dysfunction and Failure. Cardiovascular and Pulmonary Physical Therapy 19.
6. Massery M 1994. What's Positioning got to do with it? Neurology Report 18(3).
7. Destroyer A 1983. Mechanical action of the abdominal muscles, *Bull Euro Physiopatho Resp*., 19: 575.
8. Hobson L., Dean E. 1987. Review of respiratory anatomy, In Frownfelter D (ed.) Chest Physical Therapy and Pulmonary Rehabilitation: An interdisciplinary Approach, *Chicago Yearbook Medical*, 3-51.
9. Landers M, Barker G *et al*. 2003. A comparison of tidal volume, breathing frequency and minute ventilation between two sitting postures in healthy adults. *Physiotherapy Theory and Practice*, 19(2): 109-119.
10. Fang L, Sriranjani P, Taylor S J *et al*. 2006. Effect of Different Sitting Postures on Lung Capacity, Expiratory Flow, and Lumbar Lordosis; Archieves of Physical Medicine and Rehabilitation.
11. Hodges PW and Simon CG 2000. Changes in intra-abdominal pressure during postural and respiratory activation of the human diaphragm, *Journal of Applied Physiology,* 89(3): 967–976.
12. Hodges PW, Heijnen I, Simon CG 2001. Postural activity of the diaphragm is reduced in humans when respiratory demand increases, *Journal of Physiology*, 537(3): 999–1008.
13. Rothman JG 1978. Effects of respiratory exercises on the vital capacity and forced expiratory volume in children with cerebral palsy, *Physical Therapy*, 58(4): 421-5.
14. Liaw MY, Lin MC *et al*. 2000. Resistive inspiratory muscle training: its effectiveness in patients with acute complete cervical cord injury. *Archieves of Physical Medicine and Rehabilitation,* 81: 752-6.

15. Gosselink R, Kovacs L *et al.* 2000. Respiratory Muscle Weakness and Respiratory Muscle Training in Severely Disabled Multiple Sclerosis Patients, Respiratory muscle weakness and respiratory muscle training in severely disabled multiple sclerosis patients, *Archieves of Physical Medicine and Rehabilitation,* 81: 747-51.
16. Park E, Park JH *et al.* 2006. Comparison of the Ratio of Upper to Lower Chest Wall in Children with Spastic Quadriplegic Cerebral Palsy and Normally Developed Children, *Yonsei Medical Journal,* 47(2): 237 – 242.
17. Neumann P and Gill V 2002. Pelvic Floor and Abdominal Muscle Interaction: EMG Activity and Intra-abdominal Pressure, *Int Urogynecol Journal*, 13: 125–132.
18. Massery M 1991. Chest development as a component of normal motor development: Implications for paediatric physical therapists, *Paediatric Physical Therapy*, 3-8.
19. Kibler WB, Press J and Sciascia A 2006. The Role of Core Stability in Athletic Function, *Sports Medicine*, 36: 189-198.
20. Erkstrom RA, Donatelli RA, Carp KC 2007. Electromyographic Analysis of Core Trunk, Hip and Thigh Muscles During 9 Rehabilitation Exercises, *Journal of Orthopaedic and Sports Physical Therapy*, Vol 37(12).
21. Kavcic N, Grenier S, McGill SM 2004. Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*,29(20): 2319–2229.
22. Campbell SK 2003. Theoretical Foundations and Principles of clinical practice (1st edition).
23. Heyrman L, Molenaers G *et al.* 2011. A clinical tool to measure trunk control in children with cerebral palsy: The Trunk Control Measurement Scale, Research in Developmental Disabilities, 32(6): 2624–2635.
24. Cook AS, and Woollacott MH 2001. Motor Control Theory and practical applications (2nd edition).
25. Assaiante C, Mallau S *et al.* 2005. Development of Postural Control in Healthy Children: A Functional Approach, Neural Plasticity 12: 2-3.
26. Brogren E, Algra HM and Forssberg H 1998. Postural control in children with spastic diplegia: Muscle activity during perturbations in sitting. *Developmental Medicine and Child Neurology*, 38: 379-388.
27. Schenkman M. 1989. Interrelationship of neurological and mechanical factors in balance control. In P. Duncan (Ed.), Balance: Proceedings of the APTA Forum (pp. 29-41). Alexandria, VA: American Physical Therapy Association.
28. Lin JP, Brown JK and Brotherstone R 1994b. Assessment of spasticity in hemiplegic cerebral palsy. II: Distal lower-limb reflex excitability and function. *Developmental Medicine and Child Neurology*, 36: 290-303.
29. Dietz V, Ketelson UP, Berger SC and Quintern J 1986. Motor unit involvement in spastic paresis: Relationship between leg muscle activation and histochemistry. *Journal of the Neurological Sciences,* 75: 89-103.
30. Crenna P and Inverno M 1994. Objective detection of pathophysiological factors contributing to gait disturbance in supraspinal lesions. In E. Fedrizzi, G. Avanzini, andCrenna (Eds.), Motor development in children (pp. 103-118). New York: John Libbey.
31. Herbert R 1998. The passive mechanical properties of muscle and their adaptations to altered patterns of use. *Australian Journal of Physiotherapy*, 34(3): 141-149.
32. Carr J and Shepherd R 2000. A motor learning model for rehabilitation. In J. Carr and R. Shepherd (Eds.), Movement Science. Foundations for physical therapy in rehabilitation (2nd ed., pp. 33-110). Gaithersburg, MD: Aspen Publishers.
33. Horak F and Diener HC 1994. Cerebellar control of postural scaling and central set in stance. *Journal of Neurophysiology,* 72: 479-493.
34. Eliasson AC, Gordon AM and Forssberg H 1992. Impaired anticipatory control of isometric forces during grasping by children with cerebral palsy. *Developmental Medicine and Child Neurology*, 34: 216-225.
35. Veerle KS, Katie GB and Nele NM *et al.* 2006. Trunk muscle activity in healthy subjects during bridging stabilization exercises, *BMC Musculoskeletal Disorders*, 7: 75.
36. Frownfelter D, Massery M 2006. Facilitating Ventilatory Patterns and Breathing Strategies. In: Frownfelter D, Dean E, eds. Cardiovascular and Pulmonary Physical Therapy Evidence and Practice, ed. 4. St. Louis, MO.: Elsevier Health Sciences: Chapter 22.
37. Bandy WD, Sanders B 2007. Lippincott Williams & Wilkins. 2nd edition
38. Callaghan JP, Gunning JL, McGill SM 1998. The relationship between lumbar spine load and muscle activity during extensor exercises. *Physical Therapy*, 78(1): 8–18.
39. Veerle KS, Katie GB and Nele NM *et al.* 2007. Electromyographic activity of trunk and hip muscles during stabilization exercises in four-point kneeling in healthy volunteers; *European Spine Journal*, 16: 711–718.
40. Behm DG, Leonard AM, Young WB, Bonsey WA, MacKinnon SN 2005. Trunk muscle electromyographic activity with unstable and unilateral exercises, *Journal of Strength Conditioning Research*, 19(1), 193-201.
41. Lehman GJ, Hoda W and Oliver S 2005. Trunk muscle activity during bridging exercises on and off a Swissball, *Chiropractic and Osteopathy*, 13: 14.
42. Levitt S 2010. Treatment of Cerebral Palsy and Motor Delay, 5th Edition, Wiley-Blackwell.
43. Lederman E 2010. The myth of core stability, Journal of Bodywork and Movement Therapies, 14: 84-98.
44. Umphred DA 2007. Neurological Rehabilitation, 5th edition, Mosby Elsevier.
45. Alfred LS, Ingrid T 2004. Normal and Abnormal sensory motor Development. In Early Diagnosis and Treatment in Cerebral Palsy, Chapter 4.
46. Hodges PW, Richardson CA 1996b. Inefficient muscular stabilization of the lumbar spine associated with low back pain: a motor control evaluation of transversus abdominis. Spine 21: 2640–2650.
47. Hodges PW, Richardson CA 1999. Transversus abdominis and the superficial abdominal muscles are controlled independently in a postural task. *Neurosci Lett*, 265(2): 91–94.
48. Wilder DG, Aleksiev AR and Magnusson ML *et al.* 1996. Muscular response to sudden load. A tool to evaluate fatigue and rehabilitation. *Spine,* 21(22): 2628–39.
49. Muthukrishnan R *et al.* 2010. The differential effects of core stabilization exercise regime and conventional physiotherapy regime on postural control parameters during perturbation in patients with movement and control impairment chronic low back pain. Sports Medicine, Arthroscopy, Rehabilitation, *Therapy and Technology,* 2(13): 1758-2555.
50. Hodges PW, Simon CG and Richardson CA 1997. Contractions of specific abdominal muscles in postural tasks are affected by respiratory manoeuvres, *Journal of Applied Physiology,* 83(3): 753–760.

51. Massery M 2010. Breathing and Upright Posture: Simultaneous Needs, 26th International Seating Symposium March 11 – 13.
52. Hodges PW, Sapsford R, Pengel LH 2007. Postural and respiratory functions of the pelvic floor muscles, Neurourology and Urodynamics, 26(3): 362-371.
53. Akuthota V, Nadler S, cott F 2004. Core strengthening. Archieves of Physical Medicine and Rehabilitation 85(3 Suppl 1): S86-92.
54. Correˆa ECR, Be´rzin F 2008. Mouth Breathing Syndrome: Cervical muscles recruitment during nasal inspiration before and after respiratory and postural exercises on Swiss Ball. *International Journal of Pediatric Otorhinolaryngology,* 72: 1335—1343.
55. Snider L *et al*. 2007. Horseback Riding as Therapy for Children with Cerebral Palsy: Is There Evidence of Its Effectiveness? *Physical and Occupational Therapy in Paediatrics,* 27(2).
56. Blundell SW *et al*. 2003. Functional strength training in cerebral palsy: A pilot study of group circuit training classes for children aged 4-8 years. *Clinical Rehabilitation*, 17: 48-57.
57. Hall CM and Brody LT Therapeutic exercise; Moving towards function. 2nd edition, Lippincott Williams and Wilkins.
58. Ross SA and Engsberg JR 2007. Relationships Between Spasticity, Strength, Gait, and the GMFM-66 in Persons With Spastic Diplegia Cerebral Palsy, Archieves of Physical Medicine and Rehabilitation, 88.
59. Scholtes VA *et al*. 2008. Lower limb strength training in children with cerebral palsy- A randomized controlled trial protocol for functional strength training based on progressive resistance exercise principles, *BMC Paediatrics*, 8: 41.
60. Boutellier *et al*. 1992. The respiratory system as an exercise limiting factor in normal trained subjects. European Journal of Applied Physiology 65(4): 347-353.
61. Harms *et al*. 1997. Respiratory muscle work compromise leg blood flow during maximal exercise, *Journal of Applied Physiology*, 82(5): 1573-1583.
62. Persegol L, Jordan M, Viala D 1991. Evidence for the entrainment of breathing by locomotor patterns in humans, *Journal de physiologie*, 85: 38-43.
63. Verschuren O *et al*. 2007. Exercise Training Program in Children and Adolescents With Cerebral Palsy A Randomized Controlled Trial, *Arch Pediatr Adolesc Med*., 161(11): 1075-1081.

****