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Original article

Association between trunk control and chest expansion in individuals with acute and subacute stroke: Evidence from a tertiary care hospital in Sri Lanka

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ABSTRACT

Background & Aim: Stroke survival is frequently associated with significant residual disability worldwide. Impairment of trunk control, an early and well-established predictor of functional recovery, is commonly observed in individuals following stroke and affects movements across all planes. In addition, post-stroke respiratory muscle weakness may further compromise trunk stability and postural control. Moreover, respiratory muscle strength is positively linked with chest expansion. Therefore, this study aims to explore the association between trunk control and chest expansion as a newly emerging area of interest, which will contribute to advancing post-stroke rehabilitation.

Methods: We conducted a descriptive cross-sectional study at the Neurology Physiotherapy Unit, National Hospital of Sri Lanka. Chest expansion (upper and lower) was measured with a measuring tape. Trunk control, static sitting balance, dynamic sitting balance and trunk coordination were assessed using the Trunk Impairment Scale (TIS). Pearson and Spearman correlation tests were used to identify associations of chest expansion with trunk control, static sitting balance, dynamic sitting balance, and trunk coordination.

Results: Out of 84 participants recruited, 65 were males and 19 were females. Mean age was 59.64 (SD=10.31) years. Mean post stroke duration was 53.55 (SD=30.82) days. Mean TIS score was 15.54 (SD=3.52), with mean upper chest expansion and lower chest expansion values of 2.54 (SD=0.85) cm and 3.01 (SD=1.17) cm, respectively. There were significant positive correlations of lower chest expansion with static balance ($r=0.25$, $p=0.02$), dynamic sitting balance ($r=0.25$, $p=0.02$), trunk coordination ($r=0.41$, $p<0.0001$) and trunk control ($r=0.55$, $p<0.0001$). However, upper chest expansion showed a significant correlation only with static sitting balance ($r=0.28$, $p=0.01$).

Conclusions & Recommendations: There is a significant positive correlation between trunk control and lower chest expansion in acute and sub-acute post-stroke individuals. This suggests that improving chest expansion may enhance trunk control. Therefore, incorporating chest expansion exercises in the early stages of stroke rehabilitation could be beneficial, and further research should explore their impact. An integrated approach may improve functional outcomes and quality of life of this population.

Keywords: *stroke, trunk control, trunk impairment scale, upper chest expansion, lower chest expansion*

Introduction

As defined by the World Health Organization (WHO), stroke is a rapidly progressing syndrome characterized by clinical signs of focal or global brain function impairments of potential vascular origin, persisting for at least 24 hours (1). It stands as a major contributor to long-term disability in global scale. In Sri Lanka, stroke is the sixth leading cause of death and the fifth leading cause of disability. The prevalence of stroke in Sri Lanka is 10.4 per 1000 (1).

Trunk control is the ability to maintain the body's upright posture, to adjust weight shifting and to perform selective movements in the trunk to keep the center of mass within the base of support. Studies have reported that post-stroke individuals have decreased trunk control in all planes, more in the frontal plane (2). Trunk control needs to be predated to gain control of distal limb movements and is correlated with functional movements (2). The level of trunk impairment determines the level of trunk control (3). Static sitting balance, dynamic sitting balance and trunk coordination are factors which determines the trunk control (3). The ability to distribute body weight evenly (postural symmetry) and shift weight according to the task requirements is essential to maintain balance. These procedures are commonly disturbed in individuals with stroke. They frequently exhibit increased postural sway, decreased dynamic stability and impaired weight-shifting ability onto the paretic lower limb when sitting and standing. As a result of reduced ability to control the posture, they present an increased risk of falling toward the paretic side and limited functional abilities (4).

Pulmonary dysfunction is a common impairment observed in individuals following stroke, particularly among those with hemiparesis. Reduced chest wall expansion is frequently reported and may contribute to a range of complex complications during the early stages of recovery (5, 6). Evidence indicates that respiratory muscle weakness and limited thoracic mobility can result in fatigue and dyspnea during activities requiring higher levels of physical exertion, thereby restricting performance in activities of daily living (7). Post-stroke paralysis affecting the diaphragm and accessory respiratory muscles may further compromise thoracic expansion, leading to muscle shortening and fibrotic changes that reduce ventilatory efficiency (8). Importantly, improvements in respiratory function are positively associated with enhanced functional capacity (9).

Trunk control is supported by a group of muscles that also contribute to the structure and function of the thoracic cavity, including the diaphragm, pelvic floor muscles, abdominal muscles, and paraspinal musculature. The diaphragm serves as the primary muscle of respiration, while the intercostal, abdominal, and cervical muscles function as accessory respiratory muscles. Additional supportive roles are provided by the pelvic floor muscles, which assist in regulating intra-abdominal and thoracic pressures during breathing, and by the back muscles, which stabilize the thorax and maintain postural alignment. Deep stabilizing muscles, particularly the diaphragm, transversus abdominis, and pelvic floor muscles, perform integrated roles in both respiratory function and trunk stability (10). Evidence suggests a close interrelationship between respiratory and trunk control mechanisms, with studies demonstrating a positive association between trunk control and respiratory muscle strength (11). Furthermore, in individuals following stroke, inspiratory muscle strength has been shown to correlate positively with both upper and lower chest expansion, indicating that greater inspiratory muscle strength contributes to increased chest expansion (12).

Based on these findings, the hypothesis has been developed as there is an association between trunk control and chest expansion among post stroke individuals. Although several studies have explored the relationship between trunk control and lung function, respiratory muscle strength, and other factors, there are no previous studies that have been conducted to identify the relationship between trunk control and chest expansion (11). There is a scarcity of research on this topic conducted in Sri Lanka as well. Therefore, this study aims to investigate the correlation between trunk control and chest expansion among post-stroke survivors, addressing this important research gap.

Methods

Study design and participants

This cross-sectional descriptive study was conducted in the Neurology Physiotherapy Unit of the National Hospital of Sri Lanka (NHSL) over three weeks, from 18th September to 8th October 2023. It is the largest teaching hospital in Sri Lanka and the final referral centre in the country. This makes it an ideal setting to obtain a diverse sample from different parts of the country, with varying degrees of impact on their lives, thereby increasing the generalizability of the findings. The study population comprised both male and female participants aged between 20 and 75 years, diagnosed with ischemic or haemorrhagic stroke from July 2023 to September 2023, with a post-stroke duration of less than 3 months.

Before starting data collection, permission for the data collection was obtained from the director of the NHSL, the relevant consultants and the chief physiotherapist of the Neurology Physiotherapy Unit. Ethical approval has been obtained from the Ethics Review Committee, Faculty of Medicine, University of Colombo (UCP/AL/19/2019). All the participants in the study were recruited only after obtaining their written consent for participation.

Individuals with a clinical diagnosis of ischemic or haemorrhagic stroke whose time since the occurrence of the stroke was less than 12 weeks (3 months) and who were aged from 20 to 75 years were included in the study. Inward patients who had respiratory complications, participants who could not perform study-related procedures, participants with respiratory tract metastases, pulmonary diseases such as broncho-aspiration, aspiration pneumonia, hospitalized pneumonia, extra thoracic comorbidities, hemodynamic instability, and altered cognitive status that compromise the ability to perform the tests, participants who had syncope, tumours or clinical diseases which can interfere with the maintenance of sitting balance, participants who declined to provide their consent for participation were excluded.

Data collection

Data on age, gender, onset of the stroke, type of the stroke and the affected side were collected from all the participants using an interviewer-administered questionnaire.

The Trunk Impairment Scale (TIS) was used to assess static sitting balance (SSB), dynamic sitting balance (DSB), trunk coordination (COOR) and trunk control (TC) (3). The scale consists of seven domains, scored from 0 to 23 points, with three subscales: static sitting balance, dynamic sitting balance, and trunk coordination. Approximately 2 to 18 minutes were required to complete the assessment. The TIS score ranges from 0 to 23, with a higher score indicating better control and a lower score indicating less control. To perform the TIS, participants remained sitting on a stretcher without supporting the trunk and the upper limbs. Still, if the arms were hypertonic, the current position of the arms was taken as the starting position.

Chest expansion was measured using a cloth tape (13). The anatomical marks for upper chest expansion were the third intercostal space, the middle of the clavicular line, and the spinous process of the fifth thoracic vertebrae (13). For lower chest expansion, the xiphoid process and spinous processes of the 10th thoracic vertebrae were taken as anatomical marks (13). Standardized breathing instructions were given to the participants. Instructions were provided "to inhale slowly through the nose and to push against the tape measure to expand the lungs as much as they can." Then the participants were asked to breathe out completely through the mouth. Measurements were taken at the end of a complete inspiration and expiration cycle. "0" of the tape was kept on the appropriate vertebrae. The tape was held with an index finger between the participant's body and the tape to avoid generating any deformation or cutaneous folds. The inspiratory diameter was subtracted from the expiratory diameter to calculate the chest expansion value.

Each measurement was taken twice by the principal investigator to increase the reliability of the measurements. Measurements were taken with the participants sitting upright without back support; they comfortably placed their arms on their laps and legs in a neutral sitting position. Previous studies have shown that there is no impact of position (whether sitting upright or standing upright) on chest expansion values (14).

Statistical analysis

The data were analysed by Statistical Package for Social Sciences (SPSS) version 25.0 software. The normality of the data distribution was assessed using the Shapiro-Wilk test. Pearson correlation test was used to assess the association between continuous variables, but the association between continuous variables and ordinal variables was assessed using spearman correlation test (15). The two-tailed probability value was set at $p<0.05$ for statistical significance.

Results

Demographic and anthropometric characteristics of the subjects

A total of 97 participants diagnosed with stroke were initially recruited for the study. Among these, two participants were excluded due to age exceeding 75 years; six were unable to maintain sitting balance and therefore could not complete the TIS assessment; and five declined to provide informed consent. As a result, only 84 participants completed the study.

Out of 84 participants, 77.4% (n=65) were males and 22.6% (n=19) were females. The age range was 30-75 years. The mean age was 59.64 (SD=10.31) years. Sixty out of 84 participants (71.4%) had ischemic stroke. The majority of the patient's right side was affected. The Mean post stroke duration was 53.55 days (Standard deviation [SD]= ±30.82 days). According to the analysis, most of the patients (n=73) in this sample were in the sub-acute phase. The socio-demographic data are presented in Tables 1 and 2 below.

The descriptive statistics of TIS values and chest expansion measurements are presented in Table 3.

Table 1. Descriptive statistics of age and onset of stroke

Characteristic	Minimum	Maximum	Mean	SD
Age (Years)	30	75	59.64	10.31
Onset (Days)	10	92	53.55	30.82

SD: standard deviation

Table 2. Descriptive statistics of gender, type of stroke and affected side of the body

		No.	Percentage (%)
Gender	Male	65	77.4
	Female	19	22.6
Type of stroke	Ischemic stroke	60	71.4
	Haemorrhagic stroke	24	28.6
Affected side	Right	44	52.4
	Left	40	47.6

Data are presented as frequency (n) and percentages (%)

Table 3. Means and standard deviations of chest expansion and Trunk Impairment Scale values

	Mean	Standard Deviation
SSB	5.76	1.29
DSB	6.86	2.20
COOR	2.92	1.49
TC	15.54	3.52
UCE (cm)	2.54	0.85
LCE (cm)	3.01	1.17

SSB: static sitting balance, DSB: dynamic sitting balance, COOR: trunk coordination, TC: trunk control, UCE: upper chest expansion, LCE: lower chest expansion
Data are presented as mean and standard deviation (SD)

The mean score for SSB was 5.76 (SD=1.29), while the mean DSB score was 6.86 (SD=2.20). The trunk coordination subscale demonstrated a mean score of 2.92 (SD=1.49). The TC score had a mean value of 15.54 (SD=3.52). Chest expansion analysis revealed a mean UCE of 2.54 (SD=0.85) cm and a comparatively higher mean LCE of 3.01 (SD=1.17) cm. Even though trunk control is a continuous variable, subscales of TIS scores are ordinal scales (16). Consequently, the association between trunk control and chest expansion (both upper and lower) was assessed using Pearson's correlation coefficient. In contrast, Spearman's correlation was used to evaluate the relationships of static sitting balance, dynamic sitting balance and trunk coordination with chest expansion.

Table 4, 5 represents the correlation of upper and lower chest expansion with TIS values.

Following the analysis, only static sitting balance demonstrated a statistically significant correlation with upper chest expansion ($r=0.28$, $p=0.01$), indicating a weak positive association (Figure 1). None of the other variables showed a statistically significant relationship with upper chest expansion.

Conversely, lower chest expansion showed statistically significant positive correlation with all the variables (Table 4). There was a weak but significant positive association between SSB and LCE ($r=0.25$, $p=0.02$). Statistically significant fair degree of positive relationship between DSB and LCE ($r=0.45$, $p<0.0001$) and significant fair degree of positive relationship between COOR and LCE ($r=0.41$, $p<0.0001$) were also found. These findings are shown in Figure 2,3,4 respectively.

Table 4. Correlation between upper chest expansion and trunk impairment scale values

	r value	*p* value
SSB	0.28	0.01*
DSB	0.07	0.56
COOR	0.20	0.08
TC	0.19	0.08

SSB: static sitting balance, DSB: dynamic sitting balance, COOR: trunk coordination, TC: trunk control

r = correlation coefficient, p = statistical significance

**Statistically significant at p<0.05*

Table 5. Correlation between lower chest expansion and trunk impairment scale values

	r value	*p* value
SSB	0.25	0.02*
DSB	0.45	<0.001**
COOR	0.41	<0.001**
TC	0.55	<0.001**

SSB: static sitting balance, DSB: dynamic sitting balance, COOR: trunk coordination, TC: trunk control

r = correlation coefficient, p = statistical significance

**Statistically significant at p<0.05, **Statistically significant at p<0.001*

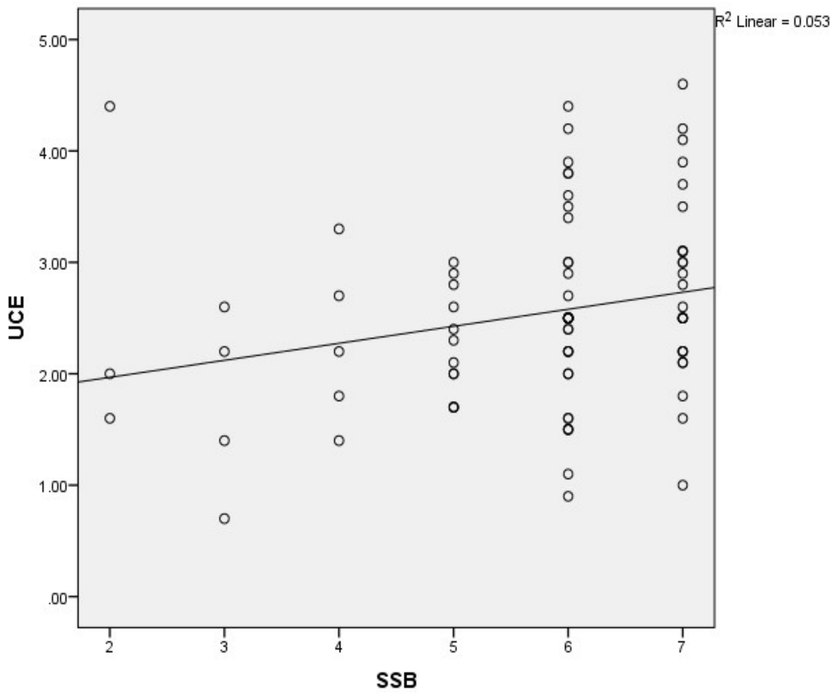

Figure 1 - Spearman (r) correlation between SSB and UCE, with r = 0.28 and p = 0.01

SSB: static sitting balance, UCE: upper chest expansion

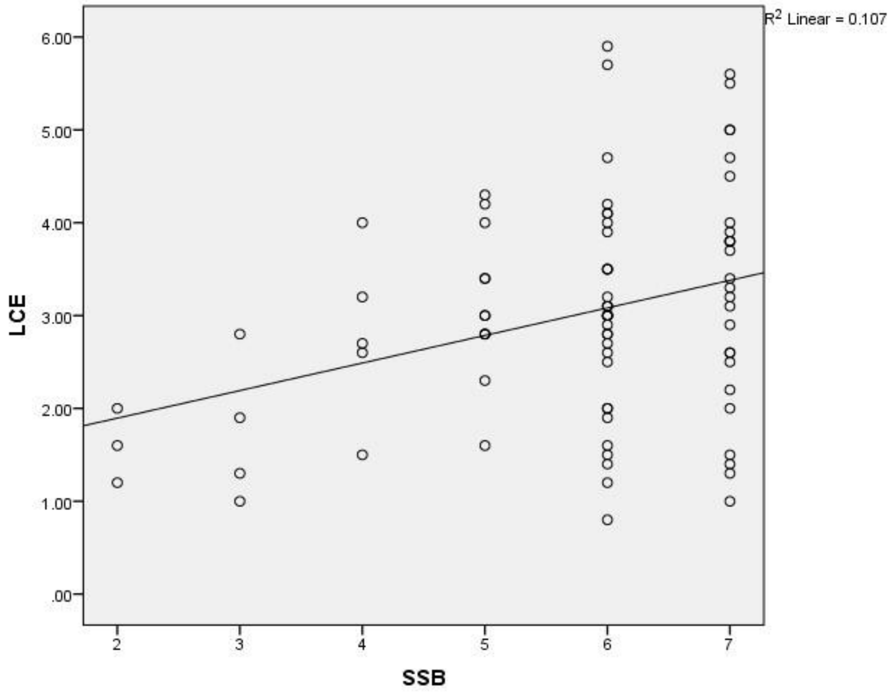

Figure 2 - Spearman (r) correlation between SSB and LCE, with r= 0.25 and p = 0.02,
SSB: static sitting balance, LCE: lower chest expansion

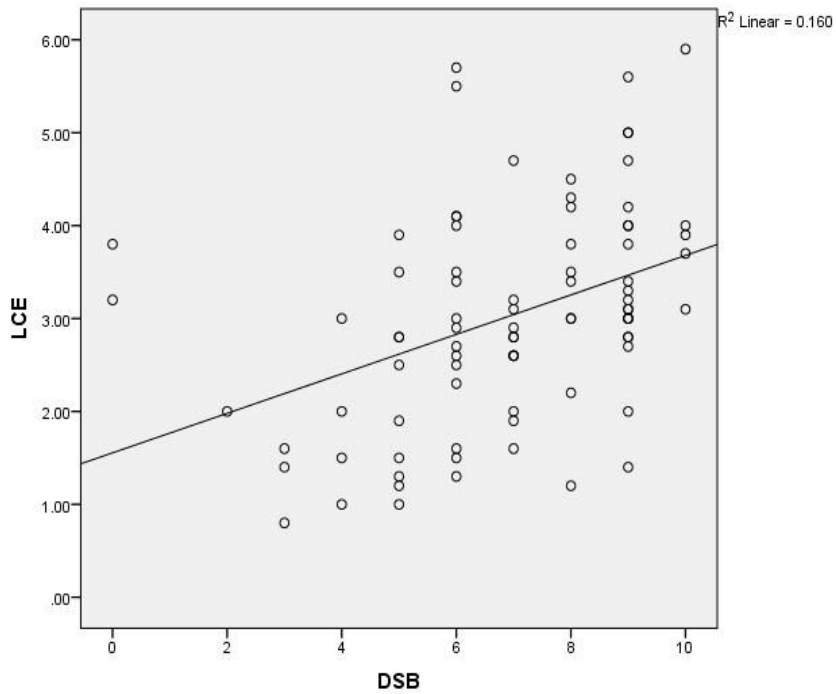

Figure 3 - Spearman (r) correlation between DSB and LCE, with r= 0.45 and p = <0.0001.
DSB: dynamic sitting balance, LCE: lower chest expansion

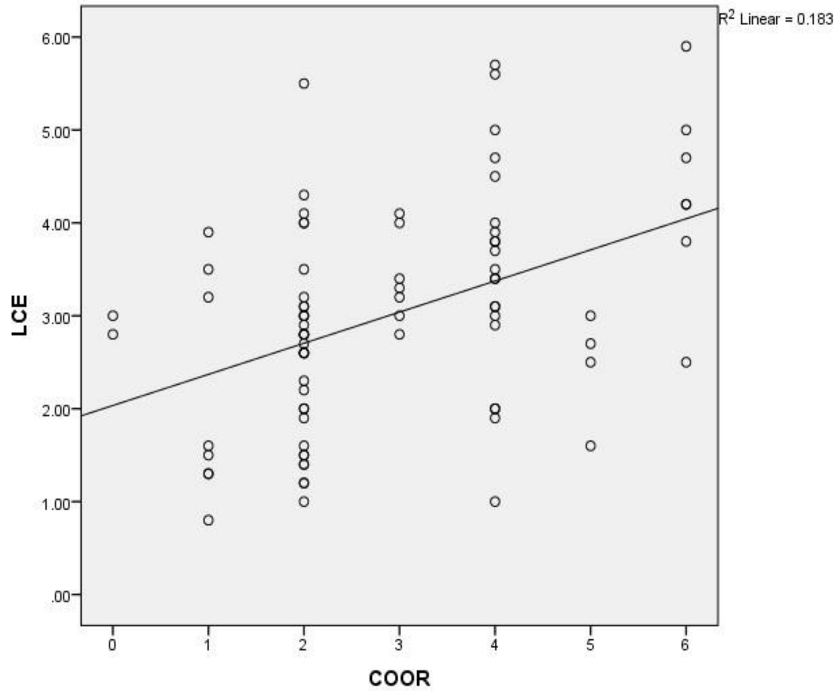

Figure 4 - Spearman (r) correlation between COOR and LCE, with r = 0.41 and p = <0.0001.

COOR: trunk coordination, LCE: lower chest expansion

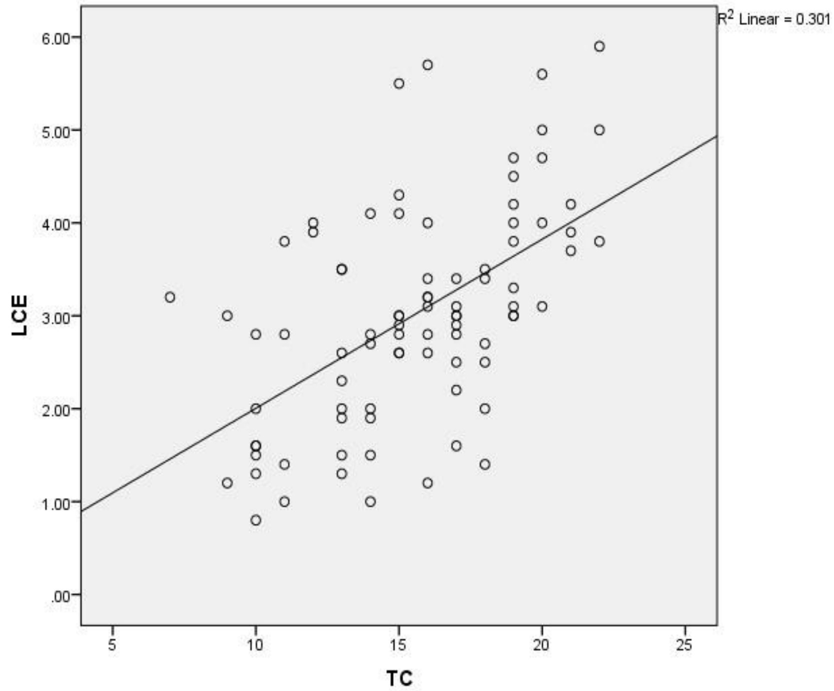

Figure 5 - Pearson (r) correlation between TC and LCE, with r = 0.55 and p = <0.0001.

TC: trunk control, LCE: lower chest expansion

The findings suggest that lower chest expansion is significantly associated with trunk control ($r=0.55$, $p<0.0001$) (Figure 5), whereas upper chest expansion does not appear to have a significant impact on trunk control.

Discussion

Lower chest expansion showed a significant positive correlation with trunk control, static sitting balance, dynamic sitting balance and trunk coordination. Upper chest expansion had no significant correlation with trunk control, dynamic sitting balance and trunk coordination, though it showed a poor correlation with static sitting balance. Moreover, lower chest expansion is more strongly correlated with dynamic sitting balance, trunk coordination, and trunk control than with static sitting balance.

According to Debouche et al (13), there is a correlation between chest wall mobility, lung function parameters, and inspiratory muscle strength. Both chest expansion measurements significantly correlate with inspiratory muscle strength and lung function, except for inspiratory capacity and FEV1/FVC. Lower chest expansion showed a stronger correlation compared to upper chest expansion, which is consistent with the findings of this study as well.

Jandt et al (11) investigated the correlation between trunk control, respiratory muscle strength and spirometry among post stroke individuals. It was an observational, quantitative descriptive study where TIS was used to measure trunk control. Respiratory muscle strength and pulmonary function have been measured by manovacuometry and spirometry, respectively. According to Jandt et al (11), there is a positive relationship between trunk control and respiratory muscular strength, though there was no significant correlation between trunk control and pulmonary function in that sample. Reduced respiratory muscle strength in stroke survivors can lead to compromised trunk stability and respiratory function. Respiratory function and trunk control affected one another (10).

In the current study, the mean (SD) TIS value was 15.54 (3.52). There were no participants who scored a total score for TIS. The observed TIS scores ranged between 7 and 22 points, with a maximum possible score of 23. The mean (SD) scores for static sitting balance, dynamic sitting balance, and trunk coordination were 5.76 (1.29), 6.86 (2.20), and 2.92 (1.49), respectively. Median values for static sitting balance, dynamic sitting balance, trunk coordination and trunk control were 6, 7,2,16 respectively in this study. The median score for TIS total for sub-acute stroke survivors is 14 in a study done by Verheyden et al (15). However, there were both acute and sub-acute individuals with stroke in our study, though the majority were in the sub-acute phase (n=73). In addition to that severity of the stroke and sociocultural differences might influence our results. According to Verheyden et al (3), a score of more than 20 on the TIS indicated normal trunk function and independence in activities of daily living. In our study, only 11 out of 84 participants scored above 20. That indicates most of the participants of our study had not achieved the normal trunk function and independence in activities of daily living yet.

Furthermore, chest expansion was impaired among the study participants, as the measured values were below the established normal range of 4–7 cm (13). Consistent with observations in healthy individuals, lower chest expansion was greater than upper chest expansion (13), a pattern that was also evident in the present study population. Rib movement mechanics can be the reason for this difference. Upper ribs (1-5) move mainly in a pump handle motion, which increases anteroposterior diameter but contributes less to circumferential expansion. Lower ribs (6-10) have a wider range of lateral movement (bucket handle movement, leading to greater measurable chest expansion (16).

In previous studies, various anatomic markers have been used to measure chest expansion. According to Debouche et al (13), the anatomical marks used to measure chest expansion in this article are the anatomical markers has been used in most of the research done so far. There are previous studies that have been done to investigate the effect of interventions on chest expansion. Most of those studies have measured only UCE and LCE. Adeogun Abiodun and Umar Dolapo (8) conducted a recent study among individuals in the acute phase post-stroke, in which only lower chest expansion was measured using tape measurement.

Though the tape method is a simple and effective way to assess chest expansion, there are more advanced and standardized tools available, such as three-dimensional motion analysis, respiratory plethysmography, and magnetometry, which provide more accurate measurements and the study did not investigate the effect of potential confounding variables such as co-morbidities, socioeconomic status, or psychological factors that could affect the variables and relationship between the variables. These are the limitations of this study.

This study aimed to investigate the relationship between trunk control and chest expansion. The analysis revealed a significant positive correlation between trunk control and chest expansion, especially with the lower chest expansion. If results are further elaborated significant positive correlations of static sitting balance, dynamic sitting balance, trunk coordination and trunk control with lower chest expansion were found. Yet, further interventional studies are recommended to obtain evidence indicating that improvements in lower chest expansion may contribute to enhanced trunk control. Research should be more focused on the effect of chest expansion on trunk control among acute post stroke population and also of chronic post stroke survivors. Impact of potential confounding variables such as co-morbidities, socioeconomic status, or psychological factors on both trunk control and chest expansion should be investigated.

According to Jung et al (2), trunk control needs to be predated to gain control of distal limb movements and is correlated with functional movements. Implementing integrated treatment approaches that effectively address these interconnected factors from early rehabilitation phases will significantly enhance the quality of life of this population, as early regain of trunk control is the factor that determines the overall post stroke functional level.

Conclusions

Integrated core and respiratory training programs represent a promising direction for future interventions. Combining core stabilization exercises (such as targeted activation of the transvers abdominis and multifidus) with diaphragmatic breathing protocols may enhance both trunk stability and respiratory efficiency. Additionally, facilitating coordinated co-contraction of trunk and respiratory muscles may further enhance postural stability and respiratory function. Together, these integrated approaches have the potential to produce synergistic improvements in trunk control and overall functional recovery.

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Author Declarations

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