Yoga—An Alternative Form of Therapy in Patients with Blunt Chest Trauma: A Randomized Controlled Trial

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Abstract

Background Yoga as an alternative form of therapy has shown positive impact on pulmonary functions, exercise capacity, behavioral changes, and inflammation in non-trauma patients. However, the efficacy of Yoga has not been studied in chest trauma patients.

Methods This randomized controlled trial was conducted at level-1 Trauma Centre. Isolated chest injury patients were randomized into either standard physiotherapy or Yoga therapy groups. Patients in physiotherapy group received conventional chest physiotherapy and Yoga therapy group received a set of Yoga exercises in addition to conventional chest physiotherapy. Primary outcome measure was changes in pulmonary function tests (PFT) at 4 weeks of discharge. Secondary outcomes were changes in quality of life (QoL), respiratory muscle strength and endurance, chest wall mobility, and levels of cytokines at 4 weeks. Data were analyzed using STATA v14.0.

Results A total of 89 eligible patients were randomized to physiotherapy (n = 46) and Yoga therapy (n = 43) groups. Demographic characteristics were comparable in both the groups. There were statistically significant improvements in PFT in the Yoga therapy group compared with physiotherapy with an increase in Forced vital capacity (p = 0.02) and Forced expiratory volume (p = 0.01) at 4 weeks. In addition, there were significant improvement in physical component of QoL, respiratory muscle endurance (p = 0.003) and axillary cirtometry (p = 0.009) in the Yoga therapy group. However, no statistically significant difference in the trends of cytokine markers seen between the groups.

Conclusion Yoga was found to be effective in improving pulmonary functions and QoL in patients with chest trauma. (Trial registered at ctri.nic.in/clinicaltrials/login.php, numberREF/2016/05/011,287).

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Introduction

Trauma is the major cause of hospitalization worldwide [1, 2]. It is also associated with high mortality and long-term disabilities [3, 4]. Chest injuries account for approximately 10–15% of total trauma burden with mortality ranging from 5 to 77% [5–7]. Chest wall, pleural and lung parenchymal injuries result in pain, impaired ventilation, impaired oxygenation and perfusion [8–10], and activation of the inflammatory cascade [11–13]. This altered inflammatory response results in systemic inflammation, acute lung injury, acute respiratory distress syndrome and multiorgan dysfunction syndrome [14, 15].

Pain, restricted chest wall movements, impaired oxygenation, higher grades of injuries lead to development of pulmonary complications. This combined with altered inflammatory response result in higher complication rates. Many observational studies analyzing higher grades of Thoracic Trauma Severity Score have demonstrated disastrous outcomes [14, 16–20]. Apart from physical dysfunction, psychological dysfunction is also significant among trauma survivors and affects quality of life in both short and long terms [21–26].

Implementation of early, effective chest rehabilitation with adequate pain control, aggressive chest physiotherapy modulates pulmonary dynamics (pain, chest wall movement, oxygenation, pulmonary functions). This minimizes pulmonary secretion retention, maximizes oxygenation, re-expands atelectatic lung and improves pulmonary functions; reduces infection and mortality rates; intensive care unit and hospital stay [27–29].

The holistic approach of Yoga involving deep breathing Pranayamas (breath control exercises) and Yogic asanas (Yoga postures) is well-established in non-trauma setting [30–32]. These Yogic practices have shown beneficial effects on cardio-pulmonary dynamics and performance, pulmonary functions, exercise capacity, immune system, mental health problems and quality of life (QoL) [33–44].

There is a dearth of literature about the effects of Yoga in trauma setting. Hence, this study was planned to examine the effect of Yoga in the clinical recovery and post injury outcomes of patients with blunt chest trauma.

Materials and methods

This prospective open-label randomized controlled study was carried out in the Division of Trauma Surgery and Critical Care at a Level I trauma center from June 2016 through August 2018. Study was approved by Institutional Ethics Committee and was registered with Clinical Trials Registry–India (Trial registered at cttri.nic.in/clinicaltrials/login.php, numberREF/2016/05/011,287).

Study population

Patients aged 18–65 years with isolated blunt chest trauma and who were managed non-operatively with or without thoracostomy tubes were recruited.

Exclusion criteria

Patients with injury duration > 24 hours, requiring ventilator support, co-existing conditions like malignancies, coagulopathy, chronic systemic diseases, patients on hormone therapy, preexisting disability interfering with Yogatherapy and pregnant women were excluded.

Randomization

Randomization was performed using computer-generated list of random numbers and allocation concealment was strictly followed. Patients were randomly allocated into standard chest physiotherapy (CTP) Group or Yogatherapy (YTP) Group. Provision for post-randomization exclusion was considered before start of study in the following instances: randomized patients requiring ventilator support for whom YTP could not be feasible and patients who wished to exit from the study due to multiple blood samplings required for the cytokines assessment. These post randomization exclusion criteria were set based on our previous experiences with trauma patients.

Intervention

All patients visiting emergency department with torso injuries were managed according to Advanced Trauma Life Support protocols. Relevant baseline investigations were done including arterial blood gas analyses, chest X-ray, pelvic X-ray and computed tomography of torso. After further screening for isolated blunt chest injuries, eligible patients were recruited. We have specific institutional protocols for analgesia and thoracostomy tube management in chest injury patients.

Oxygenation strategy

All the patients were administered supplemental oxygen by facemask during the primary survey and it was continued depending on requirement.
Analgesia protocol

Institute has departmental standardized analgesia protocol in place for the management of chest trauma patients. The analgesia protocol used in patients with chest injuries was “Sandwich Analgesic Protocol therapy.” Aim was to ensure that patients were given analgesics every six-hourly—paracetamol (1000 mg) alternating with diclofenac (50 mg). It was supplemented by regional Transdermal Drug Delivery System (Nu Patch™ manufactured by Zydus Cadila Limited—containing Diclofenac, Linseed oil, Methyl salicylate and menthol) on need basis. Medications were initially administered parenterally followed by orally as tolerated. Epidural analgesia was considered in patients with bilateral chest tubes, bilateral rib fractures, flail chest and those not responded to sandwich analgesia therapy. Opioids were not used in any patient. Same protocol was used both the groups.

CTP group

Patients received standard chest physiotherapy which included percussion, vibration, cough stimulation techniques, breathing exercises and mobilization from admission through discharge. At discharge, a set of instructions were given for home-based physiotherapy.

YTP group

Patients received Yogatherapy along with standard chest physiotherapy. Yogatherapy was delivered by trained Yoga instructor under supervision of medical experts for duration of up to maximum 1 h as tolerated on daily basis from admission through discharge. Patients were taught Pranayamas and then gradually moved on to Asanas. Patients were advised to continue Yoga at home after discharge and were given a printed Yoga booklet for reference in regional language with graphical illustrations. All patients in both arms were followed up at 1st, 2nd and 4th week of discharge.

Outcome measures and data collection

Primary outcome: Pulmonary functions (PFTs) at 4 weeks from discharge. Secondary outcomes: (1) QoL, Respiratory muscle endurance (RME), Respiratory muscle strength (RMS), Chest wall mobility (CWM) and Cytokine levels at 4 weeks from discharge; (2) Change in PFTs, RME and CWM over time from admission to 4 weeks follow-up; (3) Changes in Cytokines levels before and after intervention during hospital stay.

PFTs measured were Tidal Volume (VT), Forced Vital Capacity (FVC), and Forced Expiratory Volume in one Second (FEV1), Peak Expiratory Force (PEF) and FVC/FEV1 ratio. RME was assessed by measuring Maximum voluntary ventilation (MVV). All values were recorded in liters using Spirolyser Q13 USB and Qflow® sensor (manufacturer: FIM medical, France) [45–48].

For QoL, World Health Organization (WHO) BREF 26, a standardized assessment instrument comprising of 26 items/questions was used. It has four main domains: physical, psychological, social relationships and environment domains [49].

RMS was assessed by diaphragm ultrasound for diaphragm movements and thickness. These variables were recorded both during resting and deep respiration using Siemens ACUSON S2000 and/or SonoSite M-Turbo [50].

In CWM, chest wall excursion during deep inspiration was measured at two sites (values expressed in centimeters) using measuring tape: at the level of nipple—Axillary cirtometry and xiphi-sternum—Thoracic cirtometry [51].

Serum cytokines Interleukin (IL)-2, IL-4, IL-8, IL-10, IL-12, Tumor necrosis factor (TNF)-α and Interferon (IFN)-γ were measured. Blood samples were collected on day 0, one hour before and 2 h after interventions on day 1, 2, 3, 4 or on the day of discharge; and one blood sample during follow-up at 4 weeks. Blood samples were centrifuged, stored at −80 °C and analyzed at the end of study by enzyme linked immunosorbent assay technology using PowerWave™ XS Microplate Reader by BioTek Instruments, Inc.

Statistical analysis

Sample size was calculated taking into consideration that Yoga would reduce the hospital stay by 1 day in patients with isolated chest trauma. Thus, initial sample size was 66 patients with β-power of 80% and α-power of 5%. However, patients were continuously recruited further even after completion of sample size. Data was collected in Microsoft Excel 2010 for windows. Statistical analysis was carried out using Stata v: 14.0 for windows. Data analysis was done as per protocol basis and presented in mean (SD), and frequency (%) and median and interquartile range (IQR) wherever required. Categorical variables were compared by chi-squared test and Fischer’s test. Continuous variables were compared using independent-t test (for normal distribution) and Wilcoxon rank-sum (for non-normal distribution). Overall variables between the groups over the time were compared by GEE (generalized estimating equation).
Results

A total of 2354 poly-trauma patients were admitted during the study period. Out of which 119 patients with isolated blunt chest trauma were identified and 89 patients were recruited into the study. Post-randomization, nine patients were excluded from analysis for various reasons (Fig. 1).

Data from 80 patients, 42 in CTP group and 38 in YTP group were analyzed. All baseline demographic and clinical characteristics of both groups were comparable except the clinically detected pneumothorax which was significantly more in YTP group (Table 1).

Baseline outcome parameters viz. PFTs, RME, RMS, CWM, QoL, cytokines at admission were comparable in both groups except the physical component of QoL which was significantly more in YTP group (Table 2).

Supplemental oxygen was used in all patients in the primary survey and further on need basis. No patient received noninvasive assisted ventilation. Epidural Analgesia was used in 14 patients of CPT group and 17 patients of YTP group.

Length of stay (LoS)

The length of stay was comparable with mean (± SD) 3.7 ± 1.01 days in CTP group and 4.3 ± 2.03 days in YTP group and was not statistically significant ($p = 0.07$). The chest tube duration was 3 (2.8–4) (median-IQR) days in physiotherapy group and 4 (3–5.8) days in YTP group with $p$ of 0.05 indicating that chest tube was required for longer duration in YTP group. YTP group had statistically significant more pneumothorax ($p < 0.001$) and non-statistically significant hemothorax ($p = 0.07$) compared to CTP group at admission.

Primary outcome measures

There was statistically significant improvement in pulmonary functions at 4 weeks from discharge in YTP group with improvement in VT ($p = 0.04$, FVC ($p = 0.02$), FEV1 ($p = 0.01$), PEF ($p = 0.002$) of the YTP group. (Table 3).

Secondary Outcome Measures

There was no statistical difference in all four domains of the QoL in both groups at 4 weeks. However, there was
significant improvement in the physical domain of QoL at 4 weeks effectively nullifying the negative difference present at baseline in Yoga therapy group. The baseline physical domain of quality of life was statistically less in YTP group (49.4 ± 16.91) as compared to CPT group (55.10 ± 1 0.72) with *p* = 0.05 at the time of recruitment. However, with time, there was improvement in physical

| Table 1: Demographic and Clinical Characteristics |
|--------------------------------------------------|
| **Characteristic** | Physiotherapy (n = 42)(%) | Yoga therapy (n = 38)(%) | *p* value |
|---------------------|---------------------------|--------------------------|-----------|
| Age (years) (mean ± sd) | 41.4 ± 12.40 | 42.6 ± 11.59 | 0.65 |
| Sex | | | |
| Male | 40 (95.3) | 36 (94.7) | 0.94 |
| Female | 2 (4.7) | 2 (5.3) | |
| Duration of injury (hours) (mean ± sd) | 6.5 ± 7.17 | 8.0 ± 7.44 | 0.15 |
| Mechanism of injury (MOI) | | | |
| RTI | 28 (66.7) | 26 (69.2) | 0.72 |
| Fall | 11 (26.3) | 7 (18.0) | |
| Assault | 2 (4.7) | 3 (7.5) | |
| Fall of heavy object | 1 (2.3) | 2 (5.3) | |
| Chest wall tenderness | 42(100) | 38(100) | – |
| Clinical pneumothorax | 11 (26.2) | 24 (64.0) | < 0.001 |
| Clinical hemothorax | 1 (2.4) | 4 (12.8) | 0.07 |
| Surgical emphysema | 9 (18.4) | 8 (22.2) | 0.85 |
| Chest tube insertion | 26 (61.9) | 29 (74.4) | 0.23 |
| Chest tube duration (median-IQR) (days) | 3 (2.8–4) | 4 (3–5.8) | 0.05 |
| Epidural analgesia (n) | 14 | 17 | |
| CT rib fracture | | | |
| No rib fracture | 3 (7.1) | 2 (5.1) | 0.62 |
| 1–3 rib fracture | 8 (19.0) | 8 (23.0) | |
| 3–6 rib fracture | 22 (52.4) | 19 (48.7) | |
| 3 ribs bilateral | 0 | 2 (5.1) | |
| Flail chest | 9 (21.4) | 7 (17.9) | |
| CT contusion | | | |
| None | 23 (54.8) | 22 (56.4) | |
| 1 lobe, unilateral | 15 (35.7) | 7 (18.1) | |
| 1 lobe bilateral/ 2 lobes unilateral | 3 (7.1) | 6 (15.4) | 0.21 |
| 2 lobes bilateral | 1 (2.4) | 2 (7.7) | |
| 2lobes bilateral | 0 | 1 (2.6) | |
| CT pleural involvement | | | |
| None | 8 (19.1) | 6 (15.4) | |
| Pneumothorax | 11(26.2) | 9 (23.0) | |
| Hemo/Hemopneumothorax unilateral | 19 (45.2) | 15 (38.5) | 0.42 |
| Hemo/Hemopneumothorax, bilateral | 4 (9.5) | 8 (23.1) | |
| Tension pneumothorax | 0 | 0 | |
| ISS (median-IQR) | 9 (9–9) | 9 (9–9) | 0.70 |
| NISS (median-IQR) | 18 (9–22) | 18 (10–22) | 0.89 |
| TTSS Score (median-IQR) | 6 (5–9) | 8 (5–10) | 0.27 |
| TTSS Score Grade (n, %) | | | |
| Low grade | 34 (80.9) | 29 (74.4) | 0.48 |
| High grade | 8 (19.1) | 9 (25.6) | |

*RTI Road Traffic Injuries, CT computed tomography, ISS Injury Severity Score, NISS New Injury Severity Score, TTSS Thoracic Trauma Severity Score*
domain among YTP cohort and was comparable to physiotherapy group ($p = 0.13$).

There was significant improvement of the RME (MVV) ($p = 0.003$) and axillary component of CWM ($p = 0.009$). There was only a relative improvement in RMS as evidenced by the improvement in right diaphragm motion at resting respiration ($p = 0.06$) and during forced respiration ($p = 0.06$). The cytokine levels didn’t show any difference in both groups. (Table 4).

Using GEE longitudinal analysis was performed for outcomes to examine the effect of interventions over the time from admission to discharge. (Table 5) There was constant and significant improvement of the FVC [diff. (95% CI) 4.9 (1.270, 8.09); $p = 0.008$], FEV1 [5.12 (1.256, 8.984); $p = 0.009$], PEF [4.47 (0.834, 8.106); $p = 0.016$], RME [6.725 (3.320, 10.245); $p = <0.0001$] in the yoga group from discharge to 4 weeks. The change in VT over the time was only marginal [0.05 (-0.001, 0.118); $p = 0.056$].

Table 2 Respiratory, cytokine and quality of life parameters at admission in both groups

| Characteristic | Physiotherapy (n = 42) | Yoga therapy (n = 38) | p value |
|---------------|------------------------|-----------------------|---------|
| **Pulmonary function tests:** | | | |
| VT (ltrs) | 0.37 ± 0.12 | 0.41 ± 0.2 | 0.24 |
| FVC | 35.3 ± 9.10 | 38.1 ± 8.90 | 0.16 |
| FEV1 | 35.8 ± 10.63 | 38.7 ± 8.20 | 0.16 |
| PEF | 33.9 ± 9.80 | 34.4 ± 8.45 | 0.82 |
| FEV1/FVC | 106.5 ± 17.20 | 107.1 ± 12.20 | 0.85 |
| Respiratory muscle endurance: MVV (ltrs) | | | |
| Axillary cirtometry | 3.0 ± 0.32 | 2.9 ± 0.39 | 0.15 |
| Thoracic cirtometry | 3.8 ± 0.28 | 3.7 ± 0.41 | 0.14 |
| **Chest wall expansion (cm):** | | | |
| Axillary cirtometry | | | |
| Thoracic cirtometry | | | |
| **Respiratory muscle strength: Diaphragm motion at normal breathing (mm):** | | | |
| Right | 15.4 ± 4.14 | 15.4 ± 4.81 | 0.99 |
| Left | 20.5 ± 5.89 | 21.0 ± 6.55 | 0.73 |
| **Diaphragm motion at deep breathing (mm):** | | | |
| Right | 21.7 ± 6.15 | 21.9 ± 5.53 | 0.86 |
| Left | 27.3 ± 6.20 | 30.1 ± 9.7 | 0.12 |
| **Diaphragm thickness at normal breathing (mm):** | | | |
| Right | 1.77 ± 0.52 | 1.82 ± 0.45 | 0.65 |
| Left | 1.62 ± 0.44 | 1.62 ± 0.39 | 0.94 |
| **Diaphragm thickness at deep breathing (mm):** | | | |
| Right | 2.08 ± 0.6 | 2.1 ± 0.56 | 0.88 |
| Left | 1.93 ± 0.64 | 1.98 ± 0.62 | 0.69 |
| **Cytokines** | | | |
| IL-2 | 633.0 ± 1360.98 | 670.5 ± 1209.8 | 0.48 |
| IL-4 | 1065.8 ± 5670.7 | 315.8 ± 351.20 | 0.41 |
| IL-8 | 673.5 ± 1295.10 | 1833.2 ± 4317.73 | 0.12 |
| IL-10 | 100.91 ± 112.88 | 99.2 ± 103.78 | 0.93 |
| IL-12 | 501.4 ± 814.36 | 360.3 ± 659.56 | 0.73 |
| TNF-α | 201.3 ± 433.04 | 300.4 ± 589.90 | 0.54 |
| IFN-γ | 288.9 ± 396.27 | 323.8 ± 432.43 | 0.60 |
| **WHO QoL:** | | | |
| Physical | 55.6 ± 10.72 | 49.4 ± 16.91 | 0.05 |
| Psychological | 64.3 ± 13.57 | 61.9 ± 17.65 | 0.51 |
| Social relations | 60.2 ± 14.67 | 60.8 ± 20.96 | 0.88 |
| Environmental | 51.0 ± 13.80 | 51.1 ± 15.70 | 0.98 |

VT Tidal Volume, FVC Forced Vital Capacity, FEV1 Forced Expiratory Volume in one Second, PEF Peak Expiratory Force, MVV Maximum voluntary ventilation, IL Interleukin, TNF-α Tumor Necrosis Factor-α, IFN-γ Interferon-γ, WHO QoL World Health Organization Quality of Life
Analysis of cytokines trends during hospital stay before and after interventions in both groups showed inconsistent changes in trends with no significant differences except for IL-4 on day 1, IL-10 on day 3 which could be a chance finding. During follow up at 4 weeks levels of cytokines were comparable between both the groups. (Table 6).

| Characteristic | Physiotherapy Group | Yogatherapy Group | p value |
|---------------|---------------------|-------------------|---------|
| N = 32        | N = 27              |                   |         |
| VT (Ltrs)     | 0.54 ± 0.15         | 0.65 ± 0.24       | 0.04    |
| FVC %         | 51.6 ± 11.68        | 58.5 ± 11.68      | 0.02    |
| FEV1%         | 52.5 ± 13.7         | 61.6 ± 13.48      | 0.01    |
| PEF %         | 42.5 ± 11.49        | 53.1 ± 14.17      | 0.002   |
| FVC/FEV1%     | 106.3 ± 14.26       | 109.7 ± 10.26     | 0.30    |

Independent *t* test was used, VT Tidal Volume, FVC Forced Vital Capacity, FEV1 Forced Expiratory Volume in One Second, PEF Peak Expiratory Force.

| Characteristic | Physiotherapy Group | Yogatherapy Group | p value |
|---------------|---------------------|-------------------|---------|
| N = 32        | N = 27              |                   |         |
| Quality of life |                    |                   |         |
| Physical      | 69.7 ± 14.08        | 74.73 ± 9.99      | 0.13    |
| Psychological | 76.2 ± 11.60        | 79.8 ± 12.90      | 0.26    |
| Social        | 65.6 ± 17.67        | 70.4 ± 14.68      | 0.27    |
| Environmental | 60.1 ± 14.97        | 64.7 ± 11.68      | 0.20    |

| Respiratory muscle endurance | Physiotherapy Group | Yogatherapy Group | p value |
|------------------------------|---------------------|-------------------|---------|
| MVV                          | 45.9 ± 13.44        | 56.4 ± 12.43      | 0.0003  |

| Respiratory muscle strength (in millimeters) | Physiotherapy Group | Yogatherapy Group | p value |
|----------------------------------------------|---------------------|-------------------|---------|
| Diaphragm motion at normal breathing (Right) | 18.85 ± 5.02        | 21.15 ± 4.05      | 0.06    |
| Diaphragm motion at normal breathing (Left)  | 25.50 ± 7.44        | 26.14 ± 4.67      | 0.70    |
| Diaphragm motion at deep breathing (Right)  | 25.90 ± 7.08        | 29.03 ± 5.16      | 0.06    |
| Diaphragm motion at deep breathing (Left)   | 32.22 ± 7.55        | 35.47 ± 6.57      | 0.08    |
| Diaphragm thickness at normal breathing (Right) | 1.95 ± 0.57        | 2.04 ± 0.32       | 0.48    |
| Diaphragm thickness at normal breathing (Left) | 1.79 ± 0.47        | 1.83 ± 0.35       | 0.68    |

| Chest Wall mobility (in Centimeters) | Physiotherapy Group | Yogatherapy Group | p value |
|-------------------------------------|---------------------|-------------------|---------|
| Axillary Cirtometry                 | 3.6 ± 0.4           | 3.9 ± 0.35        | 0.0009  |
| Thoracic Cirtometry                 | 4.5 ± 0.41          | 4.7 ± 0.41        | 0.057   |

| Cytokine levels | Physiotherapy Group | Yogatherapy Group | p value |
|-----------------|---------------------|-------------------|---------|
| IL2             | 317.4 ± 660.15      | 556.6 ± 1090.57   | 0.13    |
| IL4             | 1202.8 ± 5770.68    | 1389.6 ± 5650.02  | 0.97    |
| IL8             | 665.8 ± 1482.93     | 2948.4 ± 11688.71 | 0.85    |
| IL10            | 108.5 ± 92.93       | 80.7 ± 70.31      | 0.85    |
| IL12            | 738.5 ± 2447.03     | 1138.8 ± 3972.88  | 0.67    |
| TNF-α           | 89.9 ± 73.79        | 248.6 ± 511.81    | 0.19    |
| IFN-γ           | 242.7 ± 314.84      | 355.2 ± 520.36    | 0.33    |

Independent *t* test was used, MVV Maximum voluntary ventilation, IL Interleukin, TNF-α Tumor Necrosis Factor-a, IFN-γ Interferon-γ.
Discussion

Prior to conceptualizing this study design, extensive literature review did not yield any studies pertaining to effects of yoga in trauma patients. However, there were studies involving yoga and other mind body techniques (MBT) evaluating the beneficial effects on pulmonary functions, RME, RMS, QoL and immune markers in non-trauma patients.

In our study, demographic profiles in both groups were comparable. The mean length of hospital stay (LoS) was 3.7 days in CPT group and 4.3 days in YTP group. Al-Koudmani et al. reported 4.5 days of mean LoS in chest injury patients [5]. However, Demirhan R et al. and Narayanan R et al. reported mean hospital stay of 10.7 days and 10.09 days, respectively [6, 52]. But, Park HB et al. and Bagaria et al. reported longer and varying LoS 13.5–27 days and 20.4–29 days, respectively [14, 53]. These differences could be because of associated multisystem injuries. In our study, shorter hospital stay could be because of recruitment of isolated blunt chest injury patients. YTP group had longer duration of LoS compared to CPT group though nonsignificant statistically. This could primarily be due to the need of chest tube for longer duration in YTP group compared to CPT group which was statistically significant. Secondly, patients in YTP group had significantly higher percentage of clinically detected pneumothorax and hemothorax requiring chest tube drainage in the primary survey. These could be well-corroborated signifying the severity. However, this difference was by chance because of random allocation of the patients in two groups.

Chest trauma impairs pulmonary dynamics and further negatively affects pulmonary functions [54, 55]. Hence, early chest physiotherapy effectively modulates pulmonary dynamics and hence the pulmonary functions, respiratory strength and endurance.

Table 5 Change in pulmonary functions and respiratory muscle endurance, chest wall mobility over time from admission to 4 weeks follow-up

| Characteristic | Group | At admission* | Day of Discharge* | 4 Weeks* | Diff. (95% CI)¥ | p value |
|---------------|-------|--------------|------------------|---------|-----------------|---------|
| VT (Ltrs)     | Physio | 0.37 ± 0.12  | 0.47 ± 0.17      | 0.54 ± 0.15 | 0.05 (− 0.001, 0.118) | 0.056   |
|               | Yoga   | 0.41 ± 0.2   | 0.51 ± 0.16      | 0.65 ± 0.24 |                 |         |
|               | p value | 0.25         | 0.34             | **0.04**   |                 |         |
| FVC           | Physio | 35.3 ± 9.10  | 41.9 ± 10.96     | 51.6 ± 11.68 | 4.9 (1.270, 8.609) | **0.008** |
|               | Yoga   | 38.1 ± 8.90  | 46.4 ± 10.41     | 58.5 ± 11.68 |                 |         |
|               | p value | 0.16         | 0.06             | **0.02**   |                 |         |
| FEV1          | Physio | 35.8 ± 10.63 | 41.9 ± 10.84     | 52.5 ± 13.7 | 5.12 (1.256, 8.984) | **0.009** |
|               | Yoga   | 38.7 ± 8.20  | 45.2 ± 10.64     | 61.6 ± 13.48 |                 |         |
|               | p value | 0.16         | 0.18             | 0.01       |                 |         |
| PEF           | Physio | 33.9 ± 9.80  | 37.8 ± 10.35     | 42.5 ± 11.49 | 4.47 (0.834, 8.106) | **0.016** |
|               | Yoga   | 34.4 ± 8.45  | 41.8 ± 10.76     | 53.1 ± 14.17 |                 |         |
|               | p value | 0.82         | 0.09             | 0.002      |                 |         |
| FVC/FEV1      | Physio | 106.5 ± 17.20| 105.0 ± 12.96    | 106.3 ± 14.26 | 1.003 (−3.069, 5.076) | 0.629   |
|               | Yoga   | 107.1 ± 12.20| 104.7 ± 12.67    | 109.7 ± 10.26 |                 |         |
|               | p value | 0.85         | 0.93             | 0.30       |                 |         |
| MVV           | Physio | 25.6 ± 8.50  | 31.9 ± 8.82      | 45.9 ± 13.44 | 6.725 (3.320, 10.245) | < **0.0001** |
|               | Yoga   | 27.1 ± 7.22  | 40.5 ± 10.27     | 56.4 ± 12.43 |                 |         |
|               | p value | 0.40         | 0.0001           | **0.003**  |                 |         |
| Axillary Cirtometry (cm) | Physio | 3.0 ± 0.32  | 3.3 ± 0.39       | 3.6 ± 0.4  | 0.071 (−0.071, 0.214) | 0.33   |
|               | Yoga   | 2.9 ± 0.39  | 3.4 ± 0.33       | 3.9 ± 0.35 |                 |         |
|               | p value | 0.15         | 0.10             | **0.009**  |                 |         |
| Thoracic Cirtometry (cm) | Physio | 3.8 ± 0.28  | 4.1 ± 0.35       | 4.5 ± 0.41 | 0.056 (−0.095, 0.208) | 0.46   |
|               | Yoga   | 3.7 ± 0.41  | 4.2 ± 0.42       | 4.7 ± 0.41 |                 |         |
|               | p value | 0.14         | 0.19             | 0.057      |                 |         |

*Independent t test; ¥ Generalized estimation equation analysis, VT Tidal Volume, FVC Forced Vital Capacity, FEV1 Forced Expiratory Volume in one Second, PEF Peak Expiratory Force, MVV Maximum voluntary ventilation
In multiple studies involving non-trauma patients, Pranayama have shown improvement in pulmonary functions, RMS and RME. Joshi LN et al. showed significant improvement in FVC, PEF rate and MVV with 6 weeks of Pranayama in healthy volunteers [33]. Another study also documented significant improvement in FVC, FEV1, PEF and MVV with 60 days of Pranayama [34]. Another randomized study in asthmatics showed significant improvements in FVC, FEV1 and PEF with 6 months of Yogatherapy [35]. In our study, there was significant improvement in pulmonary functions at 4 weeks in Yogatherapy group.

Several inspiratory muscle training programs (IMT) have been used to improve the strength and endurance of chest wall muscles in elderly; and in patients with chronic obstructive pulmonary disease (COPD), neuromuscular diseases and stroke. Cebriai Ianzo Md et al. found significant improvement in MVV in elderly patients with Pranayama [37]. Beckerman M et al. demonstrated significant improvement in exercise capacity and QoL using IMT in COPD patients and decrease in dyspnea, primary

| Characteristic Group | Day 1 | Day 2 | Day 3 |
|----------------------|-------|-------|-------|
|                      | Before | After | p value | Before | After | p value | Before | After | p value |
|                      | N=42 N=38 | N=42 N=38 | N=42 N=38 | N=42 N=38 | N=42 N=38 | N=42 N=38 | N=42 N=38 | N=42 N=38 |
| IL-2 Physio | 753.3 ± 1423.95 | 651.6 ± 1373.15 | 0.53 | 723.5 ± 1906.82 | 513.1 ± 1015.55 | 0.34 | 1216.2 ± 1718.47 | 1096.0 ± 1752.45 | 0.36 |
| IL-4 Physio | 565.9 ± 1049.54 | 710.4 ± 1198.87 | 0.29 | 1143.3 ± 1738.4 | 821.0 ± 1657.77 | 0.14 | 693.5 ± 881.49 | 1327.8 ± 2380.37 | 0.26 |
| IL-8 Physio | 292.3 ± 454.33 | 184.3 ± 309.19 | 0.05 | 266.8 ± 768.48 | 1291.6 ± 6139.26 | 0.32 | 399.2 ± 366.66 | 609.9 ± 708.91 | 0.31 |
| IL-10 Physio | 691.9 ± 1314.02 | 1211.0 ± 2352.53 | 0.15 | 858.7 ± 1920.63 | 418.4 ± 878.51 | 0.21 | 338.4 ± 320.33 | 343.7 ± 275.45 | 0.67 |
| IL-12 Physio | 7408.5 ± 39582.86 | 8023.5 ± 42902.06 | 0.27 | 1638.3 ± 3033.43 | 2684.4 ± 6610.75 | 0.32 | 747.7 ± 1478.88 | 705.4 ± 1500.78 | 0.39 |
| TNF-α Physio | 776.9 ± 1872.91 | 1235.7 ± 4119.79 | 0.28 | 886.3 ± 3542.33 | 917.0 ± 3268.52 | 0.98 | 767.9 ± 1196.07 | 462.6 ± 788.79 | 0.93 |
| IFN-γ Physio | 360.3 ± 879.62 | 470.2 ± 1270.06 | 0.66 | 252.4 ± 577.88 | 142.4 ± 143.34 | 0.25 | 505.8 ± 898.25 | 314.9 ± 506.89 | 0.55 |
| Yoga Physio | 279.8 ± 750.24 | 246.7 ± 445.58 | 0.81 | 389.6 ± 827.86 | 464.4 ± 1042.97 | 0.74 | 355.2 ± 596.82 | 278.0 ± 363.85 | 0.51 |
| Yoga Physio | 305.7 ± 441.85 | 329.3 ± 410.17 | 0.81 | 288.2 ± 381.56 | 185.1 ± 280.6 | 0.43 | 455.8 ± 551.25 | 324.4 ± 340.52 | 0.46 |

*Independent t test; ¥ Generalized estimation equation analysis, IL Interleukin, TNF-α Tumor Necrosis Factor-a, IFN-γ Interferon-γ
Yogatherapy, in the early stage of hospitalization, improves pulmonary functions (FVC, FEV, and PEF) at a significantly greater extent compared to standard chest physiotherapy [59]. Jung et al. showed significant correlation between diaphragm thickness on ultrasound, diaphragmatic excursion, and pulmonary function in patients with chronic stroke [60].

In our study, there was significant improvement in RME in YTP group; and it was evident at early stage and persisted throughout the study. There was only marginal improvement in RMS in YTP group at 4 weeks as evidenced by improvement in right diaphragm motion both at resting and deep respiration. This further indicates that if Yogatherapy continued for longer duration could potentially improve the strength of respiratory muscles.

CWM is an indirect measure of thoracic wall compliance and reflects the lung functions [61]. There was significant improvement in chest wall mobility in patients receiving Yoga therapy in our study.

The literature is abundant with various cytokines and their significance in immediate post-injury catastrophic events, and long-term outcomes [62]. Different MBTs including yoga have been shown to affect cytokines activity at circulating, cellular and genomic level [31]. Circulating cytokines variations are transient phenomenon and levels vary even in small scale insults to body. For changes to be apparent clinically, these MBT interventions need to be carried for longer duration. In our study, circulating cytokines were assessed and found no significant difference in cytokine trends between both groups. The follow-up was very short to show difference in cytokine profiles between the groups. Thus, for changes in circulating cytokines to be reflected, longer duration of follow-up or genomic markers’ expressions need to be studied.

Post-traumatic health-related quality of life is a significant problem and is all-time low in trauma patients. There is no single standard unified QoL questionnaire particular to trauma and many QoL questionnaires such as WHO QoL BREF, SF-12, Euro-QoL, custom designed have been used but none have predictive ability for long-term outcomes [63]. In our study, we found there was significant improvement in physical domain of QoL in Yoga group. But this needs to be followed up for longer duration to see the actual effect. It is worth noting that it is not possible to assess patients QoL before the traumatic events. With the available QoL questionnaires, there is always bias of present traumatic event confounding actual QoL.

This single center study showed that addition of Yogatherapy to standard chest physiotherapy significantly improves pulmonary functions (FVC, FEV, and PEF) at early stage of hospitalization. Yogatherapy also improves post-injury QoL, RMS, RME, and CWM significantly as compared to chest physiotherapy alone. However, Yogatherapy had no impact on circulating cytokines. This study gives insights for sustained and positive long-term outcomes using Yogatherapy as additional rehabilitation strategy in injured patients.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Ethics approval was taken from the Institutional Ethics Committee.

Informed consent Informed consent was obtained from all individual participants included in the study.

Trial registration number Ctri.nic.in/clinicaltrials/login.php, numberREI/2016/05/01287.

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