

## Effect of Yoga and Physiotherapy on Pulmonary Functions in Children with Duchenne Muscular Dystrophy – A Comparative Study

### Abstract

**Context:** Abnormal respiratory function is known to be detectable almost as soon as it can be measured reliably. Studies have identified the effect of respiratory muscle training as well as breathing exercises in improving pulmonary functions in children with Duchenne muscular dystrophy (DMD). **Aims:** This study aims to identify the add-on effect of yoga over physiotherapy on pulmonary functions in children with DMD. **Settings and Design:** One hundred and twenty-four patients with DMD were randomized to two groups. Group I received home-based physiotherapy and Group II received physiotherapy along with yoga intervention. **Materials and Methods:** Pulmonary function test (PFT) was assessed before the intervention (baseline data) and at regular intervals of 3 months for a period of 1 year. **Statistical Analysis Used:** Normality was assessed using Shapiro–Wilk normality test. The baseline data were analyzed using Mann–Whitney *U*-test to identify the homogeneity. Repeated measures analysis of variance was used to assess significant changes in study parameters during the assessment of every 3 months, both within and between the two groups of patients. **Results:** A total of 88 participants completed all the 5 assessments, with a mean age of  $7.9 \pm 1.5$  years. PFT parameters such as forced vital capacity (FVC), peak expiratory flow rate, maximum voluntary ventilation (MVV), and tidal volume during maximum voluntary ventilation (MVt) demonstrated significant improvements in Group I. In Group II, FVC and MVt significantly improved from baseline up to 1 year, whereas MVV improved from baseline up to 9 months. Tidal volume did not show any changes in both the groups. **Conclusions:** The findings suggest that introduction of yoga with physiotherapy intervention at an early age can be considered as one of the therapeutic strategies in improving pulmonary functions in patients with DMD.

**Keywords:** Duchenne muscular dystrophy, physiotherapy, pulmonary function test, respiratory function, Yoga

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### Introduction

Respiratory failure is considered to be the major cause (90%) of death in children with Duchenne muscular dystrophy (DMD) which results from weakness and degeneration of respiratory muscles including diaphragm, abdominal muscles, intercostal, latissimus dorsi, and sternomastoid.<sup>[1]</sup> The sequence of events due to respiratory muscle weakness leads to reduced lung compliance, ineffective cough, central and obstructive hypoxemia, atelectasis, repeated infections, and imbalance in ventilation-perfusion ratio.<sup>[2]</sup>

The prognosis in DMD depends to a large extent on the respiratory function. Patients with DMD develop a restrictive respiratory pattern with reduction of maximal respiratory pressures and forced vital

capacity (FVC) that implicates a risk for respiratory failure and death.<sup>[3]</sup> Following a plateau phase, in the early years, lung functions decline at a rate of 6%–8% annually.<sup>[4–6]</sup> A recent study shows a decrease of vital capacity of 10.7%/year in patients with DMD.<sup>[7]</sup> According to McDonald *et al.*, the loss of walking ability and spinal deformities can affect lung function, but age is the most important factor.<sup>[4]</sup> Consequently, measures of lung function are fundamental methods to monitor the outcome of patients.<sup>[6]</sup> Pulmonary function test (PFT) parameters such as FVC, peak expiratory flow rate (PEFR), tidal volume, maximum voluntary ventilation (MVV), and tidal volume during MVV were found to be significantly lower in children with DMD than in healthy individuals, which provides

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an insight on the presence of subclinical pulmonary dysfunction early in the course of disease that evolves later into clinical dysfunction.<sup>[8]</sup> Abnormal respiratory function is known to be detectable almost as soon as it can be measured reliably. PFT should be performed on a regular basis on patients diagnosed with DMD to understand the prognosis and to initiate early interventions as required in accordance with the indications identified.<sup>[8]</sup>

Various strategies have been adopted for respiratory management in patients with DMD. One study has shown that steroid treatment has the potential to stabilize lung function in DMD patients even in nonambulant children, in those older than 10 years, and in those in whom the medication was started after 7 years of age.<sup>[2]</sup> The rate of decline of FVC% has been reported to reduce from 4.28% to 1.36% upon initiating noninvasive ventilation.<sup>[9]</sup> Chest physiotherapy and respiratory muscle training are being administered in DMD patients, but their efficiency is not fully established. Studies have identified the effect of respiratory muscle training as well as breathing exercises in improving pulmonary functions in children with DMD. Yeldan *et al.* have showed that respiratory muscle strength is enhanced in ambulatory patients with DMD with training.<sup>[10]</sup>

Yoga is a complimentary mind–body therapy which is being practiced increasingly among Indian and Western populations. An American survey in 2004 reported that 15 million adults used yoga at least once in their lifetime and 7.4 million during the previous year, and concluded that yoga was often helpful and cost effective.<sup>[11]</sup> It has been proven that yoga as an add-on therapy in patients with DMD has an effect on heart rate variability.<sup>[12]</sup> Rodrigues *et al.* have identified that 83% of DMD patients are able to learn how to perform yoga breathing exercises and could significantly demonstrate improvements in forced expiratory volume in 1 s (FEV1) and FVC over a period of 10 months.<sup>[13]</sup> Yoga may help in improving the lifespan and quality of living of DMD individuals through its influence on pulmonary functions, which is least explored by researchers. Although the effect of yoga and physiotherapy has been studied separately, combined effect of both is not known. Yoga which is a recent trend in the field of exercise and fitness can be used as an adjunct with the regular physical therapy program. This randomized trail aims to identify the add-on effect of yoga over physiotherapy on pulmonary functions in children with DMD.

## Materials and Methods

### Participants

Children with a confirmed diagnosis of DMD were selected for the study. Boys within the age group of 5–10 years and who were self-ambulant or required minimal assistance were included for the study. The exclusion criteria were as follows: muscular dystrophy other than DMD, nonambulant

children, children with DMD who were undergoing regular yoga and physiotherapy before recruitment, children with DMD who were on steroids for more than 3 months, and associated cardiopulmonary conditions. Written informed consent was obtained from the parents or guardians of the children with DMD after explaining the nature and purpose of the study.

### Design

The study was conducted for a period of 4 years. The study was approved by the Institutional Review Board of the institution. The consort diagram explaining the procedure of the study is depicted in Figure 1. The patients were randomly allocated to two groups, i.e., Group I and Group II, using computer-generated Tippet’s random number table.

### Assessments

The demographic data and medical history of the patients were documented. PFT was assessed before the intervention (baseline data) and at regular intervals of 3 months for a period of 1 year, using the spirometry kit manufactured by Microquark Cosmed, Italy. The procedure was explained to the participants, and three measurements were recorded at an interval of 2 min. The best out of

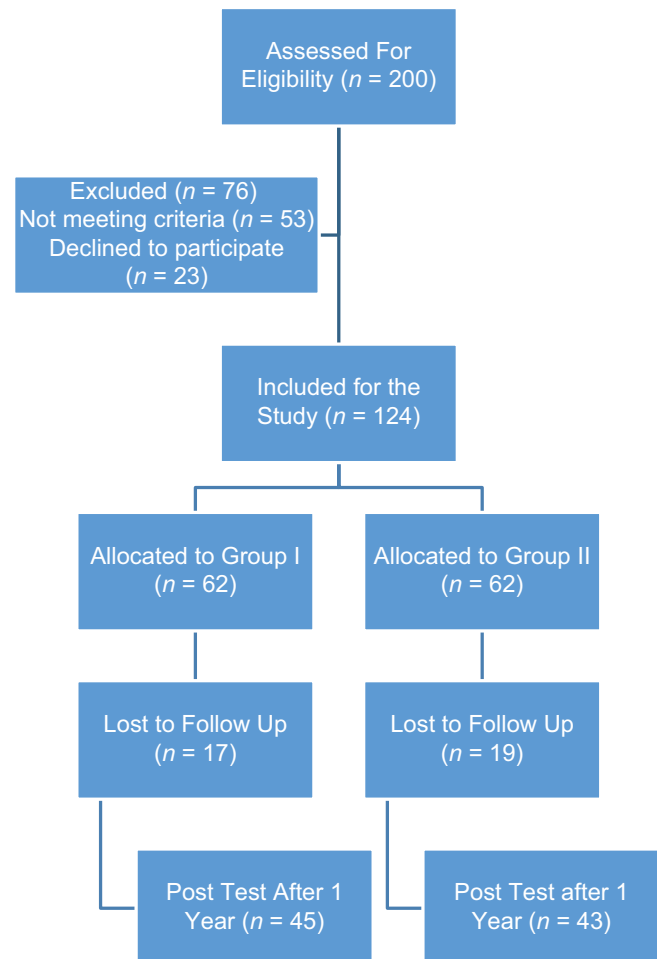


Figure 1: Consort diagram of the study

three attempts were used for analysis. The actual values of FVC, PEFr, tidal volume, MVV, and tidal volume during maximum voluntary ventilation (MVt) were considered for analysis.

**Intervention**

Group I received home-based physiotherapy exercises for two sessions a day: one in the morning and another in the evening. Group II received one session of yoga in the morning and one session of physiotherapy in the evening as home program. Each session of physiotherapy and yoga lasted for a maximum of 45 min. The detailed protocol of physiotherapy and yoga is provided in Tables 1 and 2, respectively.

Participants were made to practice physiotherapy and yoga under the supervision of physiotherapists initially for a period of 1 week. Parents were also trained during these supervised sessions in order to enable them to conduct sessions at home. Patients were then asked to perform the exercises every day at home for a period of 1 year. All the parents were instructed to maintain an exercise diary which was reviewed every 3 months at the time of each visit for the assessment during which the home program performed by the children was also reviewed.

**Data analysis**

Outcome measures for the study were assessed at 5 points of time during the study period (baseline, at 3 months, 6 months, 9 months, and after 12 months). All the variables were tested for normality using Shapiro–Wilk normality test. The baseline data of Group I and Group II were also analyzed using Mann–Whitney *U*-test to identify the homogeneity between the groups. Repeated measures analysis of variance (RMANOVA) was used to assess significant changes in study parameters during the assessment of every 3 months, both within and between the two groups of patients. Time effect (changes over the duration of treatment irrespective of type of treatment), group effect (difference between the treatment groups irrespective of the time point of assessment), and interaction effect (differences in the way the two treatment groups differ at the five time points of assessment) were also identified. *Post hoc* test was carried out using least

significant difference test. The mean difference between the baseline and 1-year follow-up data of the individuals was also analyzed according to the age groups of 5–6, 7–8, and 9–10 years of age. The data were analyzed using IBM SPSS Statistics for Windows, Version 22.0, Armonk, NY: IBM Corp. Released 2013 Statistics software.

**Results**

A total of 124 boys with DMD fulfilling the inclusion criteria were recruited and were followed for 1 year at an interval of 3 months for a total of 5 serial follow-up assessments (including baseline). The patients were randomly grouped into Group I (physiotherapy treatment regimen) (*n* = 62) and Group II (physiotherapy and yoga treatment regimen) (*n* = 62). Thirty-six (30%) individuals dropped out from the study (17 (57%) from Group I and 19 (63%) from Group II) at different time intervals and 88 participants (71%) completed all the 5 assessments. The mean age of individuals recruited for study was 7.9 ± 1.5 years. The mean height was 118.2 ± 8.4 cm (ranges between 95 and 147 cm) and the mean weight was 20.6 ± 4.3 kg (ranges between 11 and 32 kg). The mean age of onset of the disorder was 2.8 ± 0.6 years (ranges between 1.5 and 4.0 years). The mean duration of illness within the population was 5.1 ± 1.5 years (ranges from 1 to 8 years).

A comparison performed between the two groups on baseline PFT parameters showed no significant changes between them, thus maintaining homogeneity at the initial time period of the study [Table 3]. Serial evaluation of PFT parameters was carried out at baseline and after intervals of every 3 months for 1 year [Table 4]. When compared to baseline values, FVC (*P* < 0.001), PEFr (*P* = 0.05), MVV (*P* < 0.001), and MVt (*P* < 0.001) demonstrated a significant improvement in Group I. In Group II, FVC (*P* < 0.001) and MVt (*P* = 0.004) significantly improved from baseline up to 1 year, whereas MVV (*P* = 0.007) improved from baseline up to 9 months. Tidal volume did not demonstrate a significant difference after 1 year of intervention in Groups I and II (*P* = 0.448 and 0.956, respectively). Age-wise changes between the baseline and 1-year follow-up assessment on the PFT

**Table 1: Physiotherapy exercise protocol**

Exercise	Duration (min)
Passive/active ROM exercise for all joints	5
Active assisted/active breathing exercises	5
Task-oriented exercises: Rolling, lying to sitting, sitting to standing, standing, walking, climbing one flight of stairs, throwing and kicking a ball, passing the ball from left to right and then from front to back and vice versa, hand activities	15
Activity-based breathing exercises initiating with deep inspiration: Blowing pieces of paper, blowing candle placed at varying distances, blowing balloons of different sizes, blowing a party whistle, blowing bubbles with a straw, picking up objects such as small pieces of paper or small thermocol balls, sucking through a straw and then keeping it at a particular orientation	10
Stretching exercises: For trunk, chest wall, and commonly affected muscles	10

ROM: Range of motion

parameters within the groups were also analyzed [Table 5]. The age-wise comparison in Group I showed a significant improvement in FVC and MVV in all children across all age groups, PEFr in 9–10 years, tidal volume in 5–6 years,

and MVt in 7–8 years. In Group II, FVC has shown a significant improvement in children between 5 and 8 years, PEFr in 7–8 years, and MVt in 5–10 years, whereas MVV and tidal volume remained same. The RmANOVA demonstrates no significance in group effect and interaction effect for the parameters assessed in 5 timeframes. The time effect shows a significance in all parameters except for tidal volume.

**Table 2: Yoga protocol**

Exercise	Duration (min)
Sukshma and Sthula Vyayama in standing position	
Manibandha Shakti Vikasaka (wrist)	10
Anguli Shakti Vikasaka (finger)	
Kaphoni Shakti Vikasaka (elbow)	
Bhuja Bandha Shakti Vikasaka (arm)	
Griva Shakti Vikasaka I, II, III (neck)	
Purna Bhuja Shakti Vikasaka (shoulder)	
Pada Mula Shakti Vikasaka (stand on toes)	
Pada Anguli Shakti Vikasaka (toes)	
Rekha Gati Shakti Vikasaka (walking straight line)	
Pada sanchalana (heel walking)	
Exercises in supine position	
Knee cap tightening	
Dorsal stretch	
Acute thigh flexion	
Breathing exercises	
Hand stretch breathing	10
Hands in and out breathing	
Tadasana breathing	
Tiger breathing and stretching	
Shalabhasana breathing	
Sethubandhana breathing	
Straight leg raising breathing	
Asanas	
Standing: Tadasana and Vrikshasana	10
Sitting: Vakrasana and Marjalasana	
Prone: Bhujangasana	
Supine: Pavanamuktasana, Markatasana, and Sethubandasana	
Pranayama and Kriya	7
Yogic breathing	
Kapalabhati	
Nadishuddhi	
Bhastrika and Bhramari	
Meditation	
Pranavajapa: A, U, M, and its combination "AUM"	8
MSRT	

MSRT: Mind sound resonance technique

**Discussion**

This randomized comparative study aimed at comparing the effect of physiotherapy and physiotherapy with yoga in children with DMD to improve pulmonary functions. The mean age of onset of the study population was 2.8 ± 0.6 years, which is similar to other studies conducted within the same population.<sup>[14,15]</sup> The results suggest that, except for tidal volume, all other parameters of PFT have significantly improved on the course of treatment irrespective of the intervention provided. It is also noteworthy that there is no significant difference between the two groups based on the intervention administered at any point of the timeframe of follow-up visits.

The skeletal muscle tissue undergoes wasting and is ultimately replaced by fat and fibrotic tissue as the disease progresses. In the later stage of the disease, weakness of the diaphragm reduces the respiratory efficiency that in turn leads to decrease in ventilation.<sup>[16-18]</sup> Expiratory lung strength begins to decline at the age of 7 years and continues to worsen with age.<sup>[16]</sup> Thirty percent of children with DMD had a history of respiratory complications, and the frequency increased with age.<sup>[4]</sup> DMD patients may develop respiratory failure due to restrictive respiratory pattern. Pulmonary function increases until 10–12 years of age and reaches plateau, following which it declines at rate of 6%–8% annually. Vital capacity shows 10.7%/year decrease in DMD children.<sup>[2]</sup>

FVC is one of the best indicators of clinical condition of the lungs.<sup>[19]</sup> Expiratory muscles are more affected than inspiratory muscles in children with DMD, leading to a reduced quality of cough. This can cause ineffective removal of secretions and an increased chance of infections.<sup>[20]</sup> Previous studies in nonambulatory patients have found that FVC declines rapidly when standing ceases. A percentage of FVC was found to be the parameter

**Table 3: Comparison of baseline values of various pulmonary functions among the two study groups**

PFT	Group I (n-45)	Group II (n-43)	Mann-Whitney U	P
FVC (L)	0.9±0.2	0.8±0.3	768.00	0.182
PEFr (L/min)	102.9±42.4	107.3±41.3	859.00	0.840
Tidal volume (L)	0.4±0.2	0.3±0.2	753.00	0.255
MVV (L/min)	28.7±10.1	28.5±9.4	838.50	0.726
MVt (L)	0.3±0.1	0.4±0.1	781.00	0.482

Values are expressed as mean±SD; Mann-Whitney U-test was performed and the level of significance kept at P<0.05. SD: Standard deviation, PFT: Pulmonary function test, FVC: Forced vital capacity, PEFr: Peak expiratory flow rate, MVV: Maximum voluntary ventilation

**Table 4: Comparison of serial evaluation of values of pulmonary function tests in the two study groups**

PFT	Group	Baseline	3 months	6 months	9 months	12 months	Time effect <i>F, P</i>	Interaction effect <i>F, P</i>	Group effect <i>F, P</i>
FVC	I	0.9±0.2	0.9±0.3	1.0±0.3	1.1±0.3	1.0±0.3	14.165, 0.001‡	0.393, 0.681	0.08, 0.777
	II	0.8±0.3	0.9±0.3	1.0±0.3	1.1±0.6	1.0±0.3			
PEFr	I	100.6±41.7	114.8±46.7	132.1±44.0	121.6±43.5	126.8±44.2	4.818, 0.001†	0.881, 0.476	0.89, 0.347
	II	103.4±41.2	110±42.3	117.0±48.4	106.9±49.2	116.6±48.4			
Tidal volume	I	0.4±0.2	0.4±0.1	0.4±0.1	0.4±0.2	0.4±0.1	1.684, 0.154	0.424, 0.791	1.96, 0.166
	II	0.3±0.2	0.3±0.1	0.4±0.2	0.3±0.2	0.3±0.1			
MVV	I	28.1±9.7	29.0±11.6	33.3±11.7	31.7±11.0	34.6±11.0	5.569, <0.001‡	1.119, 0.348	0.05, 0.817
	II	28.7±9.4	31.8±8.6	32.5±10.2	33.6±9.5	32.6±10.7			
MVt	I	0.3±0.1	0.4±0.1	0.5±0.2	0.5±0.1	0.5±0.2	11.189, <0.001‡	0.659, 0.621	0.10, 0.753
	II	0.4±0.1	0.4±0.3	0.5±0.2	0.5±0.2	0.5±0.2			

Values are expressed as Mean±SD; RmANOVA was performed and the level of significance kept at \**P*<0.05, †*P*<0.005, ‡*P*<0.001. SD: Standard deviation, PFT: Pulmonary function test, FVC: Forced vital capacity, PEFr: Peak expiratory flow rate, MVV: Maximum voluntary ventilation, RmANOVA: Repeated measures analysis of variance

**Table 5: Age wise mean difference between baseline and 1-year values for pulmonary functions between the two study groups**

PFT values	Group	Age (years)	Difference (mean±SD)	<i>t</i>	<i>P</i>	
FVC (L)	I	5-6	-0.13±0.15	-3.011	0.011*	
		7-8	-0.19±0.18	4.385	<0.001‡	
		9-10	-0.16±0.2	2.870	0.014*	
	II	5-6	-0.28±0.15	5.859	<0.001‡	
		7-8	-0.29±0.2	5.332	<0.001‡	
		9-10	-0.04±0.17	0.817	0.432	
	PEFr (L/min)	I	5-6	11.87±56.1	0.733	0.479
			7-8	-9.21±0.64	0.914	0.376
			9-10	-49.34±0.56	3.385	0.005*
II		5-6	-7.16±49.25	0.460	0.657	
		7-8	-29.74±46.09	2.415	0.031*	
		9-10	-13.07±35.09	1.290	0.224	
Tidal volume (L)		I	5-6	-0.12±0.16	2.597	0.023†
			7-8	0.08±0.27	1.228	0.238
			9-10	0.09±0.19	1.823	0.093
	II	5-6	-0.04±0.11	1.102	0.299	
		7-8	0.01±0.21	0.211	0.836	
		9-10	-0.01±0.34	0.077	0.940	
	MVV (L/min)	I	5-6	-7.19±7.29	3.556	0.004†
			7-8	-6.65±8.24	3.327	0.004†
			9-10	-7.62±11.54	2.380	0.035*
II		5-6	-5.48±10.99	1.495	0.173	
		7-8	-6.12±10.95	2.017	0.067	
		9-10	-0.12±11.76	0.034	0.973	
MVt (L)		I	5-6	-0.07±0.11	1.411	0.186
			7-8	-0.13±0.19	-2.867	0.014*
			9-10	-0.11±0.18	1.119	0.296
	II	5-6	-0.19±0.3	3.976	0.002†	
		7-8	-0.17±0.16	3.632	0.002†	
		9-10	-0.09±0.16	2.974	0.013*	

Values are expressed as mean±SD; Paired *t*-test was performed and the level of significance level at \**P*<0.05, †*P*<0.005, ‡*P*<0.001. SD: Standard deviation, PFT: Pulmonary function test, FVC: Forced vital capacity, PEFr: Peak expiratory flow rate, MVV: Maximum voluntary ventilation

of pulmonary function that was most strongly correlated with age and scoliosis measurements.<sup>[19]</sup> Mc Donald *et al.* reported 0.3% decline in FVC at ages 7–10, 8.5% decline

at 10–12 years, and 6.2% decline after 20 years of age.<sup>[4]</sup> Annual spirometry is recommended for Duchenne children older than 6 years as they can have FVC values lower

than 80% of predicted as early as 7 years of age.<sup>[20,21]</sup> As this disease has a characteristic stage-wise deterioration, a planned and proactive approach to respiratory care is advocated and appropriate surveillance, prophylaxis, and intervention are needed.

### Effect of physiotherapy on pulmonary functions

Physiotherapy improves muscle strength, reduces the progression of joint contractures and spinal deformity, improves respiratory functions, prolongs ambulation for as long as possible, and maintains the best level of health.<sup>[22,23]</sup> Topin *et al.* suggested that specific training improves respiratory muscle endurance in DMD and the effectiveness of training appears to be dependent on the quantity of training.<sup>[24]</sup> In our study when compared to baseline values, with PT intervention, FVC, MVt, PEFr, and MVV significantly improved from baseline to 1 year. FVC and MVV are important parameters of PFT which are reflective of the intercostal and diaphragm muscle strength. Hence, the intervention has helped in improvement/maintenance of muscle strength of the respiratory muscles. PEFr also improved after physiotherapy which suggests that there was an increase in the flow of oxygen into the bronchioles and hence increased ventilation.

Various methods are used in the treatment of DMD to improve respiratory function. This includes respiratory muscle training, resisted inspiratory muscle training using valves, breath stacking with resuscitation bags, and glossopharyngeal breathing.<sup>[25]</sup> These methods need specialists' presence along with some equipment needed all the time. Chances of development of fatigue and further deterioration of respiratory muscles are another complication of vigorous respiratory training.<sup>[25]</sup> In comparison to this, yoga which is a holistic approach is relatively simple to follow at home with little training, providing maintenance as well as improvements in the disease course.

### Effect of yoga on pulmonary functions

Practice of yoga in the form of low-intensity rhythmical movements with mindfulness is known to improve the coping skills with physical and emotional stresses effectively.<sup>[26]</sup> The yoga asanas are done with mindfulness to achieve both physical and mental well-being and harmony. We have used the holistic approach suitable for DMD children and included *Sukshma* and *Sthula Vyayama* (low-exertion exercises), breathing exercises, *Pranayama* and *Kriyas* with awareness and relaxation, asanas, and guided meditation. Six weeks of *Pranayama* practice in healthy volunteers have found to reduce respiratory rate and increase FVC, FEV1%, MVV and PEFr.<sup>[27]</sup> Similar beneficial effects were observed by Makwana *et al.*, after 10 weeks of yoga practice, with increase in inspiratory and expiratory pressures which

suggests that yoga training improves the strength of respiratory muscles.<sup>[28]</sup>

Overall relaxation and calming the mind through physical and breathing practices is the primary goal of yogic practices. Yoga in the form of *Pranayama* has an effect on limbic system, hypothalamic medullary axis, and medullary cardiovascular centers, which might have influenced the cardiorespiratory system.<sup>[29]</sup> *Pranayamas* also help in increasing respiratory capacity, whereby helping to suspend respiratory cycle for a longer duration with lesser effort.<sup>[30]</sup> One of the studies showed that *Pranayama* and meditation added along with regular physiotherapy in adult patients with neurological disorder showed improvement in the quality of sleep.<sup>[31]</sup> Yoga has neurocardiac beneficiary effect by reducing vagal tone as well as reducing the catecholamine, angiotensin II concentrations, and increasing bioavailability of nitric oxide.<sup>[12]</sup> Slow yoga breathing decreases chemoreflex responses to hypoxia, and hypercapnia in healthy practitioners with increased FVC and PEFr after 3 months of practice.<sup>[32]</sup>

The study observed significant improvements in the PFT parameters on the course of treatment irrespective of the intervention provided. The improvements were steady and more pronounced in younger children. Yoga intervention showed significant improvements in the pulmonary function parameters such as FVC and MVt after 1 year, whereas MVV showed a significant improvement from baseline up to 9 months. There are certain advantages of using yoga as a therapeutic intervention in children with DMD. Yoga asanas in which the thorax and spinal movements are used, there is a natural movement occurring in the costovertebral joints of the thorax and the ribs.<sup>[33]</sup> This movements can maintain the mobility in the thoracic cage which is essential for prevention of the reduced compliance of the cage in the due course. In our study, thoracic spine and rib cage movement is evident by means of *Vakrasana* and *Bhujangasana*.

### Comparing yoga and physiotherapy on pulmonary functions

No studies are available which have evaluated the effect of yoga on serial assessment of PFT in DMD. In our study, we observed that FVC, MVV, and MVt improved significantly at every 3-month follow-up and were sustained for a period of 1 year with combined therapy with yoga and physiotherapy. In our study, the abnormalities in PFT parameters indicated subclinical pulmonary dysfunction as none of the patients demonstrated any respiratory symptoms. This may evolve later in to clinical respiratory dysfunction, which makes it imperative to start respiratory muscle training early in the disease course to slow down its progression.

These evidences collectively show that physiotherapy and yoga practices improve overall respiratory

function by increasing the respiratory muscle strength, maintaining the resilience of lung tissue, and improving the lung capacities. Based on these objective evidences of the effect of yoga on pulmonary functions, the same could be extrapolated to explain the improvements noted in PFT parameters in our study population. As the pulmonary dysfunctions are subclinical in DMD children, it is imperative to assess pulmonary functions at an early age and introduce appropriate interventions which will offer higher benefit in improving pulmonary functions through which assisted ventilation may be delayed in the disease course by which the life expectancy may be expanded.

## Conclusions

The early introduction of a pulmonary rehabilitation protocol helped in maintaining and improving the pulmonary functions in patients with DMD. Our findings provide evidence that yoga has an add-on effect along with physiotherapy intervention at an early age, which can be considered as one of the therapeutic strategies in improving pulmonary functions in children with DMD.

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## Conflicts of interest

There are no conflicts of interest.

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