Original Research Article

Hatha Yoga: Effect On Lung Volumes Including Diffusion Capacity In Uncomplicated Type 2 Diabetes Mellitus

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Abstract

Background: The science of yoga has its origin thousands of years ago. With prevailing unhealthy and stressful lifestyles, yoga is seen as both complementary and integrative approach to achieving better health. Today, Diabetes Mellitus (DM) is an epidemic which is engulfing whole world at a very fast pace. In recent years, lung impairment has been seen in DM irrespective of drug therapy. It's the dire need of the hour to devise a protocol that can actually slow down the progression of diabetes and hence, this study was done to evaluate the effect of yoga on lung functions in Type 2 Diabetes Mellitus (T2DM). **Objectives:** To assess the effect of hatha yoga on lung parameters including diffusion capacity in T2DM patients in comparison to conventional therapy alone. To compare lung functions in T2DM patients before and after yoga. **Material and Methods:** Randomized Control Trial was carried out with Sixty Uncomplicated T2DM patients (35-55 years of age) who were equally divided into YOGA and CONTROL group. CONTROL group received only conventional therapy including medication and restricted diet for DM while YOGA group underwent yoga along with conventional therapy for 8 weeks. Pre- and Post-study assessments of lung functions was done in both the groups. **Statistical Analysis**: Repeated measure ANOVA followed by Tukey's test. **Results:** YOGA group patients showed a significant (p-value<0.05) improvement in their lung functions post study. **Conclusion:** Yoga can be used as an adjunct to conventional treatment for DM, for improvement of pulmonary parameters and delay in complications of DM.

Keywords: Diabetes Mellitus, Yoga, Mind-Body Therapy, Lung Function Tests, Pulmonary Diffusing Capacity.

Introduction

Diabetes Mellitus (DM) is characterised by hyperglycaemia and chronic state of inflammation. It is not a single disease entity as thought earlier, but a syndrome that affects almost every organ system in our body.

The burden of diabetes has steadily increased across the globe, with India contributing a major part of the global burden.[1]

Type 2 Diabetes Mellitus (T2DM) is the commonest form of diabetes constituting nearly 90-95% of the diabetic population in any country. It is a complex condition known to have multiple underlying and interrelated metabolic aetiologies linked to relative or absolute insulin deficiency.[2]

Schulyer et al was the first to suggest that lung may also be a target organ in diabetes mellitus.[3] The Copenhagen City Heart Study and the Fremantle

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Diabetes Study have also supported the hypothesis of reduced lung functions in diabetic cases.[4,5]

The currently known underlying mechanisms for lung dysfunction in diabetes include hyperglycaemia, autonomic neuropathy, oxidative stress, microangiopathy of alveolar capillaries and pulmonary arterioles, non- enzymatic glycosylation of tissue proteins, collagen and elastin changes in the basement membrane causing its thickening, alteration of connective tissue, surfactant dysfunction and malfunction of respiratory muscles.[6]

Due to increased protein catabolism, there is decreased respiratory muscle strength. Neuropathy of phrenic nerve may cause diaphragmatic paralysis.[7] All these changes are associated with both restrictive and obstructive lung function impairment, including reduction in Forced Expiratory Volume in 1 second (FEV_1), Forced Vital Capacity (FVC), Diffusion Lung Capacity (DLCO),[8] and Lung Elastic Recoil[9] in diabetes. Reduction of DLCO in diabetic patients is a combination of a decrease in pulmonary capillary blood volume and alveolar-capillary membrane conductance, both are expressions of diabetic microangiopathy and lung involvement [10].

In addition, there is a mounting evidence that chronic psychological stress can also cause worsening of diabetes.[11] As in most of the chronic illnesses; mobility, emotional balance, and self-esteem decline due to dependency, restricted lifestyle and long-term medication, these are related to unhappiness and psychological distress. This causes a vicious cycle of increased stress and increased insulin resistance.

Hence, the successful management of diabetes not only requires glycaemic control but also reduction of overall stress and inflammation leading to microangiopathy and further complications of this disease. All this can be achieved by individually tailored diet plan along with medications [Oral Hypoglycaemic Agents (OHA) ± Insulin] and most importantly, some form of therapy that apart from physical fitness can bring emotional stability as well.

Yoga is one such mind-body approach and have been studied in diabetes as a means of decreasing stress-related hyperglycaemia.[12] Yoga means 'union' of body and mind by controlling the modifications of mind. Though, history of yoga dates back to 2700 B.C. (pre-Vedic period), Sadhguru during post-classical period (800 A.D.-1700 A.D.) introduced concept of Hatha yoga by giving greater importance to the asanas, kriyas and pranayama. Hatha is derived from Sanskrit: '*ha'* represents sun or prana, the vital force, and '*tha'* represents moon or mind, the mental energy. So, hatha yoga means the union of the pranic and mental forces. In fact, it means the union of prana and mind with the Self.

Hatha yoga involves three main components. First component is Asana, also known as postures-movement series that are specifically designed to improve strength and flexibility. Asana is a specific position which opens the energy channels and psychic centres. By developing control of the body through asana, the mind is controlled. Second, it focusses on controlled breathing via pranayama. Pranayama is usually considered to be the practice of controlled inhalation and exhalation combined with retention. Controlling the breathing process is seen as a vital way to control the body and quiet the mind. Lastly, there is samadhi or meditation i.e. state of oneness.

Yoga increases parasympathetic/vagal control of the heart and reduces sympathetic activation via decreased stress levels, as well as reduces systemic inflammation[13] and hence complications. Yogic asanas and pranayama are known to improve breathing patterns due to which there is much efficient perfusion of a greater number of alveoli as respiratory bronchioles are widened. Yogic regimen may also change the environs at the bronchioles and the alveoli to facilitate diffusion and exchange of gases at respiratory membrane.

Even though yoga practices are known to bring down the fasting blood glucose and oxidative stress,[14] very scanty literature is available to evaluate the beneficial effects of yoga on lung parameters, especially on diffusion lung capacity and transport of gases across alveoli in diabetic patients. Hence, the present study aimed to assess the role of yogic interventions on lung functions in Type 2 diabetic patients on conventional therapy.

We hypothesized that the use of yogic intervention along with conventional drug therapy and diet modification for DM will help in improvement of lung functions as compared to the conventional therapy alone. The primary objective of our study was to compare the lung parameters including DLCO in T2DM patients on conventional therapy and in T2DM patients on both conventional + yoga therapy.

Material and Methods

Our study was conducted in the Department of Physiology and Medicine, University College Medical

Sciences (UCMS) and Guru Teg Bahadur (GTB) Hospital, Delhi.

Selection Criteria

Diagnosed Uncomplicated Type 2 diabetic patients [according to revised American Diabetic Association (ADA) criteria] attending regular Medicine Out Patient Department (OPD) in GTB Hospital, Delhi and undergoing conventional treatment [drug therapy (OHA) + diabetic diet] were recruited for our study. Selection of the subjects was done considering certain inclusion and exclusion criteria as:

Inclusion Criteria

- Age: 35-55 years.
- Duration of diabetes in the subjects was between 0 to 10 years.

Exclusion Criteria

- Patient unwilling to do yoga or who were practicing yoga earlier as well.
- Patients with

✓ Extreme mobility issues.
✓ T2DM with any known diabetic complication like nephropathy, retinopathy, peripheral neuropathy, coronary artery disease, cerebrovascular accident.
✓ Any other metabolic disease like hypothyroidism.
✓ Acute respiratory tract infection in preceding 3 weeks.
✓ Chronic respiratory diseases like Pulmonary cox, COPD, asthma.
✓ Any known interstitial lung disease.
✓ Alcoholism & Smoking.

Study design

Our study was an Interventional Randomized Control Trial.

As shown in our study plan in ***Figure 1***, initially 116 subjects with T2DM were assessed for eligibility. Out of those, based on our selection criteria, finally 60 patients were included in the study. Patients were then randomly and equally divided into two parallel groups: YOGA group had to do yoga along-with conventional therapy and CONTROL group only received conventional therapy throughout the study for 8 weeks. All subjects underwent complete physical and clinical assessment at the onset of study.

Randomization

Randomization was done using a randomized block technique (matched pairing was done for age, sex and duration of DM; 30 pairs were made) followed by random allocation within pairs to either YOGA or CONTROL group by sealed envelope technique. The random assignment was performed by an assistant who was blind to the experimental design. Both the groups had 30 patients each. Since, double blinding was not possible, as ours was an interventional study; statistician and researcher who carried out the assessments were blinded to the intervention and treatment status of the patients.

Assessments

After segregation into groups, a baseline recording of Lung Functions including DLCO was recorded in all the patients in the Cardio-Pulmonary Laboratory of Physiology Department, UCMS, Delhi. After the basal recording of all the parameters, YOGA and CONTROL group were subjected to their respective intervention for 8 weeks. Both groups underwent assessment for the outcome measures at the end of study as well.

Intervention

YOGA group underwent regular supervised yogic regimen which included asana, pranayama and dhyana for 6 times a week, done for 8 weeks for an average of 40 - 45 minutes daily along with Oral Hypoglycaemic Agents (OHA) and diabetic diet. CONTROLS received only conventional therapy in the form of medication and diet restriction. Yoga was done under expert guidance of highly trained yoga specialists in the yoga centre in Physiology Department of UCMS, Delhi under Central Council for Research in Yoga and Naturopathy. Yoga was performed in quiet and clean surroundings from 11:30 am – 12:30 pm. Subjects were instructed to keep a time gap of minimum 4 hours for performing yoga after meals. They were instructed to carry some eatables like biscuits in case of any hypoglycaemic episode during the session. Strict compliance of every patient was recorded by maintaining regular attendance. Figure 2 shows yogic regimen followed by YOGA group.

Diet: The advice was given to focus on vegetarian diet with restriction on oil and foods with high glycaemic index; and more emphasis was given on green leafy vegetables, fruits and to have meals regularly and on time.

Test Procedure

Lung Functions were recorded using Computerized Medisoft Expair, a self-calibrating computerized spirometer, HYP'AIR Compact model of cardio-respiratory testing machine manufactured by **P** K Morgan, India, that fulfils the criteria for standardized lung functions as specified in the ATS statement (Snowbind workshop on standardization of spirometry ,1979) [15] and provides a detailed analysis of predicted and measured values.Subjects were made comfortable and were explained the entire procedure before the recording. Adequate demonstration was given till the subject completely understood the instructions. A total of three recordings were carried out and the best one fulfilling the criteria of reproducibility and validity was considered for analysis. To measure the pulmonary functions accurately, subjects were asked to perform the test with maximum possible effort. The ambient temperature between 18-24^{0}C was maintained in the laboratory. All tests were done in sitting position during morning hours. The subject was connected to the mouth piece and was asked to breathe normally in order to familiarize himself with the equipment with nose clip applied.Once a regular tracing of the tidal volume was obtained (three to four quite tidal breaths), the subject was instructed to breathe depending on the parameter to be assessed.

- For Vital Capacity (VC), patient was asked to breathe in and out as maximally as possible.
- For Forced Vital Capacity (FVC), patient inhaled fully and forcefully followed by forceful, rapid and deep exhalation.
- For Minute Voluntary Ventilation (MVV), patient was instructed to take deep and rapid breaths for 10 seconds which was later calculated for a minute.
- For DLCO, single-breath breath-holding technique was employed.

DLCO or Transfer Factor of Lung for CO. In this technique, subject inhaled a known volume of gaseous mixture [Trace gas: He (Helium) 14%, Measurement gas: CO (carbon monoxide) 0.28%, oxygen at 21% and rest nitrogen.]. The gas concentrations are measured by analysis of an alveolar volume collected in a balloon at the end of maneuver. DLCO was calculated by the inbuild software from the total volume of the lung, breath-holding time i.e.10 seconds, and the initial and final alveolar concentrations of CO.

Ethics statement

Ethical clearance was taken from the Institutional Ethical committee for the study. Prior to participation, the purpose of the study was explained to all the subjects and their informed consent was taken according to the ethical principles of the Ethical Committee of our institution.

Statistics: Data was analysed using IBM SPSS Statistics 20 software (by IBM Corporation, USA). Two factors: repeated measure ANOVA followed by Tukey's test at 5% level of significance were used. Hence, Probability value (p-value) ≤ 0.05 was considered significant. Results were expressed as Mean ± Standard Deviation (SD).

Results

Table 1: Comparison of age, sex and duration of DM between YOGA and CONTROL Group

Groups	Age (years)(SD)	Sex (M/F)	Duration (years)
YOGA	44.53 ± 5.178	15F/15M	4.82 ± 1.178
CONTROL	45.40 ± 5.315	13F/17M	4.75 ± 1.12
p-Value	0.5249	0.612	0.8231
Tukey's Significance	Non- Significant	Non- Significant	Non- Significant

At the beginning of our study, the subjects were matched for age, sex and duration of DM and then randomised into groups, such that the difference in the above stated parameters should not be statistically significant as shown in **Table 1**.

Intergroup Comparison (YOGA vs CONTROL w.r.t time)

Table 2: Comparison of Lung Functions between YOGA and CONTROL at the onset of study

FVC (L) (mean±SD)		PEFR (L/s) (mean±SD)	MVV (ml/min) (mean±SD)	DLCO (ml/mm Hg/min) (mean±SD)
2.78 ± 0.548	2.88 ± 0.394	5.10 ± 0.984	71.15 ±3.089	19.20 ± 2.421
2.80 ± 0.469	2.81 ± 0.534	5.41 ± 0.819	72.18 ±3.454	20.31 ± 2.110
0.904	0.535	0.187	0.233	0.062
Non-Significant	**Non-Significant**	**Non-Significant**	**Non-Significant**	**Non-Significant**

Table 2 shows that the difference between the mean values of FVC, VC, Peak Expiratory Flow Rate (PEFR), MVV and DLCO of YOGA and CONTROL group were statistically insignificant at the onset of study.

Table 3: Comparison of Lung Functions between YOGA and CONTROL at the end of study

FVC (L) (mean±SD)		PEFR (L/s) (mean±SD)	MVV (ml/min) (mean±SD)	DLCO (ml/mm Hg/min) (mean±SD)
3.24 ± 0.517	3.26 ± 0.421	6.51 ± 0.962	77.22 ±3.227	23.83 ± 2.686
2.83 ± 0.483	2.88 ± 0.514	5.55 ± 0.811	73.21 ± 2.803	19.58 ± 2.758
0.0024	**0.0027**	**0.0001**	**0.00**	**0.001**
Significant	**Significant**	**Significant**	**Significant**	**Significant**

On comparison of YOGA and CONTROLS at the end of 8 weeks, there was statistically significant improvement in all the lung functions recorded including DLCO in YOGA group; as shown in **Table 3.**

Intragroup Comparison (Pre-study Vs Post-study w.r.t group)

Table 4 :Comparison of Lung Functions in CONTROLS before and after 8 weeks

FVC (L) (mean±SD)		PEFR (L/s) (mean±SD)	MVV (ml/min) (mean±SD)	DLCO (ml/mm Hg/min) (mean±SD)
2.80 ± 0.469	2.81 ± 0.534	5.41 ± 0.819	72.18 ±3.454	20.31 ± 2.110
2.83 ± 0.483	2.88 ± 0.514	5.55 ± 0.811	73.21 ± 2.803	19.58 ± 2.758
0.814	0.612	0.509	0.721	0.253
Non-Significant	**Non-Significant**	**Non-Significant**	**Non-Significant**	**Non-Significant**

Table 4 shows changes in the values of FVC, VC, PEFR, MVV and DLCO over time in CONTROLS. There was a slight improvement in all lung functions except diffusion capacity which showed a slight reduction, though none of them was statistically significant.

Table 5: Comparison of Lung Functions in YOGA group before and after 8 weeks

FVC (L) (mean±SD)		PEFR (L/s) (mean±SD)	MVV (ml/min) (mean±SD)	DLCO (ml/mm Hg/min) (mean±SD)
2.78 ± 0.548	2.89 ± 0.394	5.10 ± 0.984	71.15 ±3.089	19.20 ± 2.421
3.24 ± 0.517	3.26 ± 0.421	6.51 ± 0.962	77.22 ±3.227	23.83 ± 2.686
0.0015	**0.0009**	**0.0001**	**0.0001**	**0.0001**
Significant	**Significant**	**Significant**	**Significant**	**Significant**

In our study, when we compared lung functions in YOGA group before and after yoga as shown in ***Table 5***, there was statistically significant increase in all the parameters including DLCO.

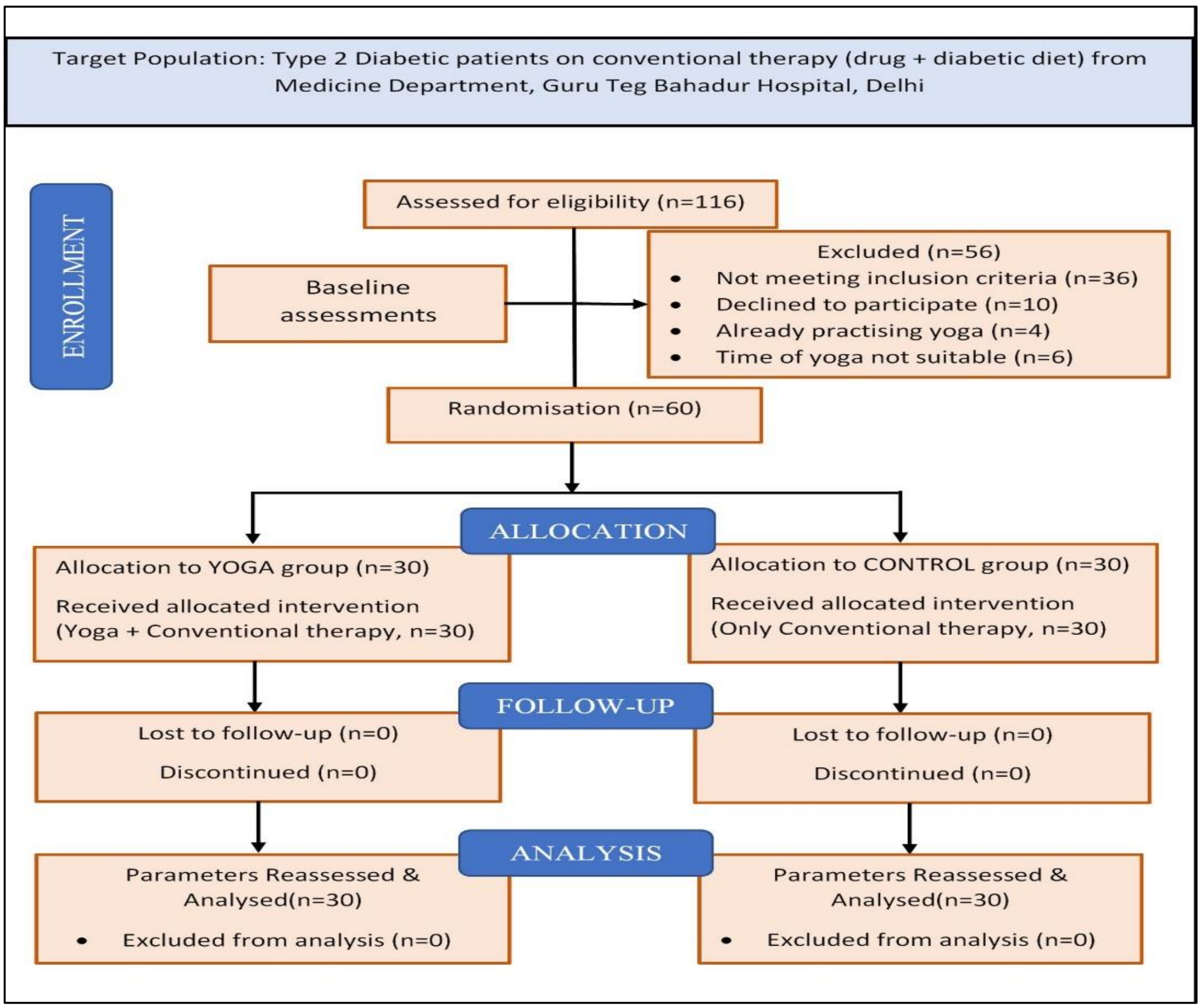

Fig 1: CONSORT flow diagram of our study protocol over 8 weeks

1. **Om Ucharan** [3 times]

2. **Asanas** were done for 15 – 20 minutes and followed the sequence:
    - *Tadasana* (Palm tree Pose): [2 times-each cycle for 15 seconds]
    - *Trikonasana* (Triangular Pose): [2 times-15 seconds hold on each side]
    - *Paschimottanasana* (Front Leaning Pose): [3 times- 15 seconds to 1 minute hold at a time]
    - *Shavasana* (Corpse pose): [2 minutes]
    - *Mandukasana* (Frog pose): [3 times- 1 minute hold]
    - *Pawanmuktasana* (Wind Relieving Pose): [3 times- 30 seconds to 1 minute hold]
    - *Bhujangasana* (Cobra Pose): [3 times- 15 seconds hold]
    - *Shavasana* (Corpse pose): [2 minutes]

3. **Pranayama** was done for 18-20 minutes and had following deep breathing exercises:
    - *Bhastrika* (bellows breath): 4 min (inhalation: exhalation=1:1, slowly done)
    - *Kapalbhati* (frontal brain cleansing): 6 min. (forceful but controlled contraction of abdominal muscles during exhalation)
    - *Anulom-vilom*: 8 min. (Inhalation/retention/exhalation- initially 1:1:1, gradually increasing to 1:2:2)

4. **Dhyana** (Meditation)
    - Omkar meditation: 10 minutes

Fig 2: Detailed Yogic regimen consisting of asana, pranayama and dhyana followed by yoga group

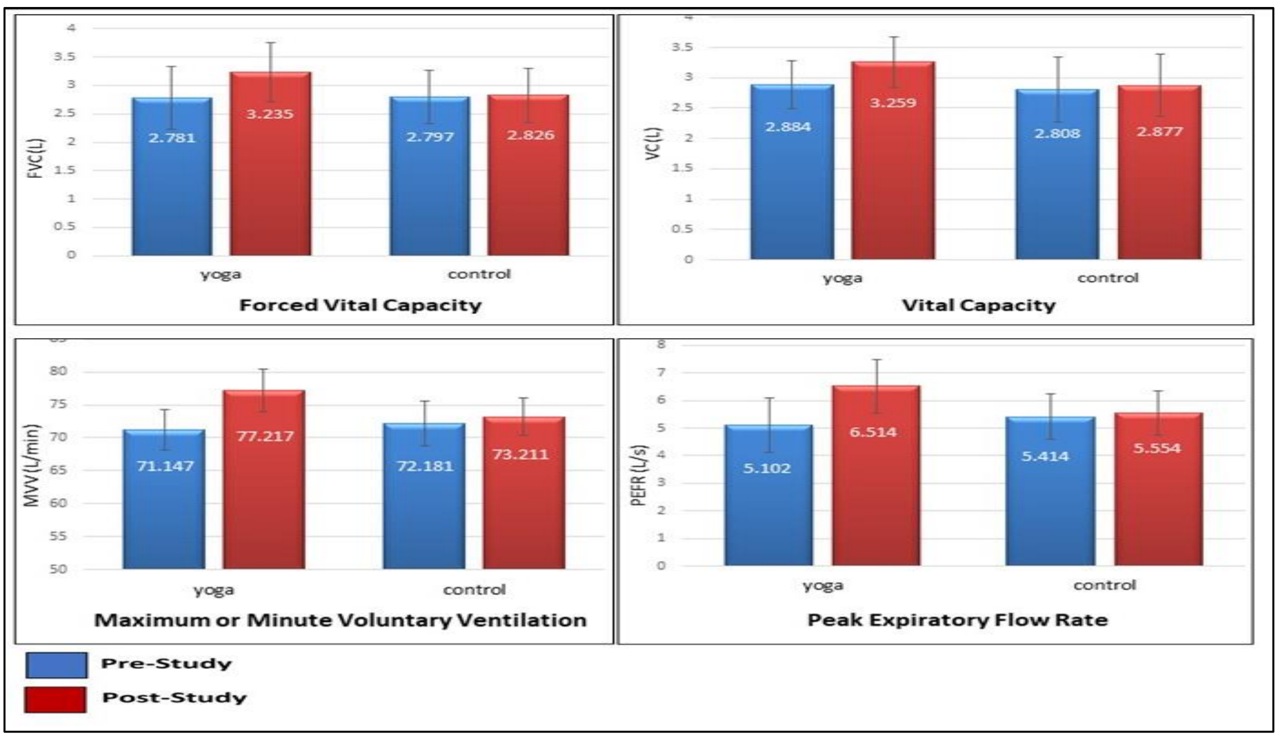

Fig 3: Bar diagrams showing changes in Lung Functions (FVC, VC, MVV & PEFR) in YOGA and CONTROL group, pre-study and post-study

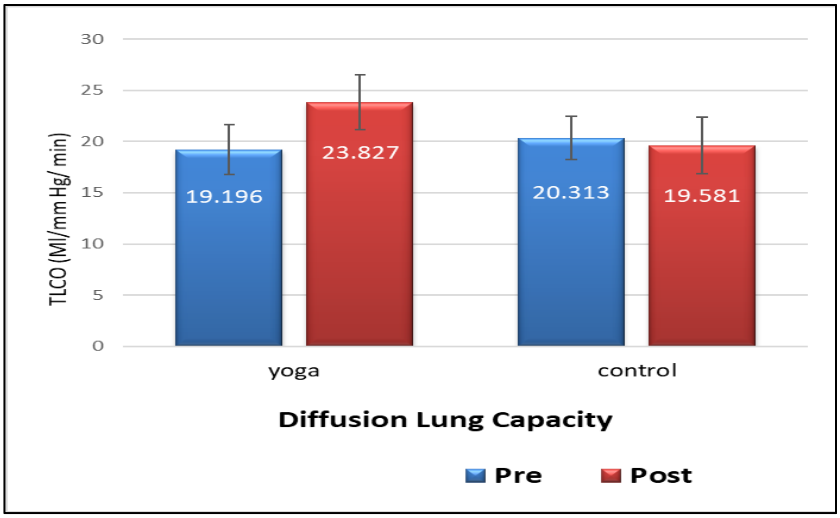

Fig 4: Bar diagrams showing changes in DLCO in YOGA and CONTROL group, pre-study and post-study

Discussion

Diabetes Mellitus is a blanket term used for a group of debilitating and devastating illnesses arising as a result of chronic hyperglycaemia. The incidence and prevalence of diabetes and its complications are increasing day by day at an exponential rate. Today, India is the diabetes capital of the world. The diabetic population in the country is close to hitting the alarming mark of 69.9 million by 2025 and 80 million by 2030. This denotes that the developing country is expected to witness an increase of 266%.[16]

The hallmark of T2DM is chronic inflammation which lead to the formation of Advanced Glycation End-products (AGEs), and is the most likely pathogenic mechanism underlying mechanical pulmonary dysfunction in diabetic subjects[17] along with microangiopathy. However, in comparison to the involvement of the vessels in the kidneys, clinical manifestations of diabetic microangiopathy in the lungs are much delayed.[18]

Therefore, lung function tests can be a reliable indicator to follow the progression of systemic microangiopathy in diabetics. And, in view of increasing burden of T2DM in homo sapiens, importance of stress relieving therapies as in yoga comes into play.

In our study, the values of FVC, VC, PEFR, MVV and TLCO showed a statistically significant improvement after 8 weeks of yoga training. FVC increased by 16%, VC by 13%, MVV increased by 8.5% and PEFR showed increase of 27% (***Figure 3***). Diffusion capacity was also increased by 24% (***Figure 4***). These results were in accordance with the observations of the earlier studies.

Shankarappa et al in their study on 50 adult patients showed a significant increase in FVC, FEV1, PEFR and Breath holding time after 6 weeks of prayanama.[19]

In an uncontrolled (pre–post) study of 24 Indian adults with an established diagnosis of T2DM, participants demonstrated significant increase in FEV, FVC, PEFR and MVV following completion of a 40-day yoga program.[20] A recent study by Ambareesha et al demonstrated similarly significant increase in FVC, VC and PEFR when 35 undergraduate medical students of both the genders where subjected to 6 weeks of regular pranayama training.[21]

All these studies including many others have explained various mechanisms by which yoga helps in improvement of lung functions. Comprehensive yoga's approach to breathing involves training of respiration in bodily positions that result in more opening of lungs so the same breath is more efficiently employed across lung function.

During pranayama training, regular controlled inspiration and expiration for prolonged period along with increased retention leads the lungs to inflate and deflate maximally and cause strengthening and increased compliance of the respiratory muscles.[22,23] Pranayama is said to be most effective when ratio of inspiration/pause/expiration is focussed upon and the goal is to improve this ratio over days slowly and progressively. A nasal breath employed in pranayama also allows the diaphragm to descend more deeply and thereby increase lung function and ventilation.

Breathing exercises employed in pranayama are consciously controlled respiratory events that are known to improve the function of the respiratory diaphragm and intercostal muscles, in a graded manner with time. Overall, better trained respiratory muscles subsequently augment plastic adaptation of the respiratory system and improved diaphragm movement. Hence, regular practice of controlled breathing leads to an improved respiratory function across a 24-hour period and not only during the time of practice.

Slow breathing techniques like anulom-vilom and brahmari augment cerebral blood flow and oxygenation, improve neuronal activities in the brain centres, including those present in the limbic areas, hypothalamus, and medulla, and improve sympathovagal outflow.[24] Thus, decreased tracheobronchial smooth muscle tone activity, may lead to decreased air flow resistance and increased airway calibre, which causes more efficient perfusion of alveoli and hence, improvement of dynamic parameters of the lung function test.[25]

Various factors affecting diffusion capacity are endothelial surface area (increases with size of subject), thickness of alveolar-capillary membrane, pulmonary capillary blood volume and haemoglobin concentration, and distribution of ventilation and ventilation-perfusion relationships. Yoga improves the circulation; thereby causing better perfusion of tissues. Another advantage of yogic breathing is that it is a kind of vertical breathing resulting in alveoli opening of both the lungs evenly and adequately thus providing larger alveolar surface for exchange of gases. Hence, larger the surface available for gas exchange, better is diffusion.[26] Additionally, "*Om*" chanting and meditation stabilizes the brain, removes negative thoughts, increases energy, improves mind and body relaxation within minutes of practice.[27]Yoga is a slow and static type of muscular exercise. Hatha yoga, since ancient times has been used by yogis for the relief and elimination of all kinds of diseases and defects. It is true that the practices require more time and effort on the part of the patient than the conventional therapies, but in terms of permanent, positive results, as well as saving the enormous expenditure on medicines and their side effects, yogic exercises are certainly more worthwhile.

The most promising aspect of including yoga as an alternative to any other form of exercise is that it can be performed by older patients having limited joint mobility or who are physically unfit or who feel less comfortable in crowd as in gym and aerobic centres or parks. Additionally, today's COVID situation of limiting or avoiding social gatherings is a blessing in disguise for yoga and meditation, as these are best practised in secluded and peaceful environment.
However, small number of patients and short duration of intervention are the major limitations of our study. Additionally, more conclusive data could have been derived on aetiology of diabetes if we have had included inflammatory markers in our study which was not possible due to resource constraints.

Conclusion

In spite of continuous development of new drug treatment protocols and improved health care infrastructure, T2DM has become an unsurmountable burden over human race. So, it's the necessity to go back to our traditional ways of living. One such simplest and most effective way is practicing yoga. To conclude, we can safely say that yoga can be used in the management of DM as it can slow the progression of the disease when used in conjunction with other standard treatment modalities.

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