



muscle strength and can be altered in disease states even when other commonly measured pulmonary function tests show little abnormality (6). In an earlier work, we have found that yoga training for 12 weeks results in a significant improvement in MEP and MIP in normal young volunteers (7). In the same study, we also observed a significant increase in handgrip strength (HGS) after yoga training and this is in agreement with the findings of other workers (8, 9, 10). However, the effect of yoga training on handgrip endurance (HGE) has been studied by only a few workers. While Tran et al (10) have reported a significant increase in muscular endurance after 8 weeks yoga training program, Dash and Telles (11) have concluded that yoga training does not increase muscle endurance. Handgrip dynamometry is an indicator of muscle function and nutritional status. As an objective and accurate physiological test that is easy to perform, it can be used as a bedside test to predict pre-operative nutritional status and post-operative complications (12). Keeping this in mind, we planned to study the effect of yoga training on these parameters. Since most of the studies on the effect of yoga training on pulmonary functions have been conducted on subjects above 18 yr in age, the present study was carried out on school going children from younger age (12–15 yr) group.

## METHODS

**Subjects and Training:** 40 student volunteers of either gender studying in 8th standard at Government Higher Secondary School, Indira Nagar, Pondicherry were motivated and recruited for the present study. They

had no previous exposure to yoga training and none of the subjects had a history of substance abuse. Respiratory and cardiovascular diseases were ruled out by their history and clinical examination. Their age was 12 to 15 ( $13.21 \pm 0.10$ , SEM) years, weight 20 to 57 ( $34.97 \pm 1.24$ , SEM) kilograms, height 1.3 to 1.66 ( $1.48 \pm 0.01$ , SEM) meters and body mass index (BMI) 8.33 to 23.30 ( $15.90 \pm 0.44$ , SEM) units. After briefing about the study protocol, informed consent was obtained from them as well as their parents. The subjects were divided randomly into two groups of 20 each.

*Group I (yoga group)* : Group I subjects were taught the following *asans* and *pranayams*: *talasan*, *utkatasan*, *trikonasan*, *ardhamatsyendrasan*, *bakasan*, *pavanmuktasan*, *navasan*, *noukasan*, *matsyasan*, *pashchimottanasan*, *halasan*, *bhujangasan*, *shalabhasan*, *sarvangasan*, *shvasan*, *mukh-bhastrika*, *mahat yoga pranayam*, *nadi shuddhi* and *savitri pranayam*. Each pose was held for 30 seconds and a short period of rest was given between the poses. Each *pranayam* was performed nine times. *Shvasan* was performed at the end for ten minutes. Detailed description of these techniques is given in standard texts on yoga (13, 14).

The subjects underwent yoga training over a period of 2 weeks. After the training period, 45 minute practice sessions were held regularly, Monday through Saturday, for a total duration of 6 months under our direct supervision.

*Group II (control group)* : Group II subjects did not receive any yoga training. They were asked to study in a classroom

while Group I subjects were undergoing yoga training.

**Parameters:** 2–3 days prior to pre-training recordings, the subjects were familiarized with the laboratory environment and their anthropometric measurements were taken. They were given instructions about the experimental procedures and practice trials were administered until we were satisfied that the subjects performed the test as required of them. Pre and post training measurements were taken about 2 hours after a light breakfast.

*Handgrip strength and endurance:* HGS (mm Hg) was measured with the dominant hand gripping an inflated cuff of a mercury manometer while the subject was sitting comfortably in a chair. The arm was extended in front at the shoulder level and kept horizontal to the ground. For determining HGE, the subject was asked to maintain 1/3rd of HGS in a sustained squeeze for as long as possible and the time (sec) was noted. In all our subjects, right hand was dominant hand. Dash and Telles (8) have reported that hand grip strength of right hand is greater than that of left hand.

*Respiratory pressures:* MEP was determined by asking the subject to blow against mercury column of a manometer after taking in a full breath. The maximum level at which the mercury column could be maintained for about 3 sec was noted. MIP was determined by asking the subject to perform maximum inspiratory effort against the mercury column after breathing out fully. MIP that could be maintained for about 3 sec was noted. It was ensured that

the subjects did not use oral muscles to develop pressure or tongue to block the tubing.

*Spirometry:* FEV, FEV<sub>1</sub> and PEFr were measured by computerized spirometer (Spirocheck, Morgan, England). The subject was instructed to take maximum inspiration and blow into the mouthpiece as rapidly, forcefully and completely as possible. It was ensured that a tight seal was maintained between the lips and the mouthpiece of the spirometer.

The above mentioned parameters were measured before and after the 6 months study period in both the groups. For each parameter, three trials at three minute intervals were given and highest of the three values was used for statistical analysis.

#### Statistical analysis

The data was analyzed using Student's paired 't' test to compare the pre and post training values of both the groups. P value of less than 0.05 was accepted as indicating significant difference between the compared values.

## RESULTS

Yoga training of six months produced a significant ( $P < 0.05$ ) increase in HGS and HGE in our group I subjects (Table I). It also produced a highly significant ( $P < 0.001$ ) increase in MEP, MIP, FEV, FEV<sub>1</sub> and PEFr. In contrast, the changes in these parameters in the control group subjects were statistically insignificant.

TABLE I: Handgrip strength (HGS), handgrip endurance (HGE), maximum expiratory pressure (MEP), maximum inspiratory pressure (MIP), forced expiratory volume (FEV), forced expiratory volume in 1st second (FEV<sub>1</sub>) and peak expiratory flow rate (PEFR) before and after the 6 months study period.

Parameters	Yoga group		Control group	
	Before	After	Before	After
HGS (mm Hg)	129.53±8.96	147.37±9.57*	133.30±7.54	133.00±8.53
HGE (sec)	46.21±4.38	57.16±5.86*	45.05±2.87	50.90±4.99
MEP (mm Hg)	29.32±4.63	46.05±5.5**	29.75±4.31	36.00±3.93
MIP (mm Hg)	30.26±3.07	65.53±5.86**	34.75±3.11	38.00±3.31
FEV (L)	1.85±0.07	2.21±0.09**	1.98±0.06	2.11±0.07
FEV <sub>1</sub> (L)	1.84±0.07	2.12±0.09**	1.90±0.05	2.03±0.07
PEFR (L/min)	271.21±14.82	336.16±19.04**	270.40±10.28	287.05±12.69

Values are Mean ± SEM for 20 subjects in each group. \*P<0.05, \*\*P<0.001.

## DISCUSSION

In the present study, HGS and HGE increased significantly after six months of yoga training. This is consistent with our earlier finding that yoga training produces a significant increase in HGS (7). Raghuraj et al (9) have reported that *pranayam* training results in significant increase in the HGS of both hands. On the other hand, Dash and Telles (11) have concluded that yoga training produces an increase in motor speed for repetitive finger movements, but not in strength or endurance. The increase in HGS and HGE in our yoga group is consistent with the findings of Tran et al (10) who have reported that eight week hatha yoga training results in a significant increase in isokinetic muscular strength and isometric muscular endurance. Raju et al (15) have also reported that yoga training results in a significant increase in maximal work output with a significant reduced level of oxygen consumption per unit work. Some of the yogic postures in our study like *bakasan*, *bhujangasan* and *shalabhasan*

involve sustained isometric contraction of the shoulder, chest and arm muscles. Consequent improvement in the strength and endurance of these muscles can explain the significant increase in HGS and HGE. Although HGS and HGE are simple methods to assess skeletal muscle strength and nutritional status, normative data on these parameters is limited. These tests can be used to determine the effectiveness of health-promoting programs like yoga training. They can also be used as objective clinical measures for determining the severity of the disease process and effectiveness of rehabilitation programs. Hence, there is a need to carry out further studies on these parameters in normal subjects and patients with neuromuscular and nutritional disorders.

In the present study MEP and MIP increased significantly following six months of yoga training in our group I subjects. Our results do not agree with those of Gopal et al (16) who have reported a lower MEP in yoga trained subjects as compared to

untrained ones. However, the present findings are consistent with those of our earlier work (7). Chen and Kuo (17) have reported that inspiratory muscle endurance is greater in physically active men than sedentary men. The increase in MEP and MIP in our yoga group indicates that yoga training improves the strength of the expiratory as well as inspiratory muscles. *Mukh-bhastrika* included in our present training program involves powerful strokes of exhalation, which trains the subject to make full use of diaphragm and abdominal muscles. Slow, deep and full exhalation and inhalation during *mahat yoga* and *savitri pranayams* also train the respiratory muscles. Respiratory muscles are vital and evaluation of their performance is important. Respiratory pressures are specific and sensitive indices of respiratory muscle strength and they are easy to measure and reproducible. Black and Hyatt (6) have demonstrated that their values are altered before there is alteration in other commonly used pulmonary function tests. Hence, evaluation of respiratory muscle strength is important from physiological as well as clinical point of view. Since the highest MEP is obtained at lung volumes of more than 70% of total lung capacity and the highest MIP is obtained at lung volumes of less than 50% of total lung capacity (16), we measured MEP after full inspiration and MIP after full expiration.

Our present findings that pulmonary function tests such as FEV, FEV<sub>1</sub> and PEFr increased significantly after yoga training is consistent with earlier studies. Bhole et al (1) have reported a significant increase in vital capacity after three weeks of yoga training. In a study on 287 college students

(both men and women), Birkel and Edgren (2) found that yoga training produced a significant improvement in vital capacity across all categories of subjects that included smokers, asthmatics as well as those with no known lung disease. Joshi et al (5) have reported that pranayam training improves ventilatory functions in the form of increase in FEV, FEV<sub>1</sub> and PEFr. Makwana et al (3) and Yadav and Das (4) also found a significant increase in these parameters after yoga training. Thus our results are consistent with the findings of other workers who have reported beneficial effects of yoga training on pulmonary function as measured by spirometry. Vital capacity is a critical component of good health and its determination is important for normal subjects, smokers and patients with respiratory and cardiovascular conditions. PEFr is an inexpensive, accurate and simple test for measuring airway resistance and strength of expiratory muscles.

The baseline values of our subjects are lower than those reported in the literature. The values for European subjects are known to be higher than the age and sex matched Indian subjects and this has been attributed to racial background and nutritional status. Our subjects were sedentary, from low socio-economic background and had low weight and BMI. Hence their baseline values were lower than the values reported in the literature. Yoga training resulted in appreciable and statistically significant improvement in all the parameters measured in this study. In conclusion, the present study shows that six month yoga training produces a significant improvement in handgrip strength and endurance,

respiratory pressures and spirometric values and this improvement is appreciable in underweight children.

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