Section VIII

Effect of eleven months of Yogic training on physiological responses in Surya Namaskar
8. Effect of eleven months of Yogic training on physiological responses in *Surya Namaskar*

8.1 Introduction

The effects of physical training on different organs and organ functions have been shown in a series of studies (5, 24). The effect of exercise training on the cardiovascular systems is well documented (31, 67, 83, 95, 103, 112, 212, 231, 234). The weight and volume of the heart increase with long term aerobic training with greater end diastolic volumes noted both at rest and during exercise. Cardiac hypertrophy is a common feature associated with exercise training. This effect is characterized by an increase in the size of left ventricular cavity and a modest thickening of its wall (123). Resting and submaximal heart rate decrease during aerobic training (118). Training causes the heart’s stroke volume to increase both at rest and during exercise. This change results from an increase in internal ventricular volume and possibly an increase in the contractility of the ventricle (223). Endurance training enhances left ventricular systolic volume regardless of age (44). An increase in maximum cardiac output is the most significant change in cardiovascular function associated with aerobic training. The increased cardiac output results from improved stroke volume. Training increases the amount of oxygen to be extracted from the circulating blood (108). This increase in a-v O$_2$ difference may be more important in contributing to improved aerobic capacity with training than it is among younger individuals (97, 200, 202). A trained person performs submaximal exercise with lower cardiac output than an untrained person. This probably occurs as a result of specific local changes associated with training. As the muscles ability to deliver, extract and use oxygen increases, less regional blood is required to meet the active tissues oxygen needs. Aerobic training causes a large increase in total muscle blood flow during maximal exercise because of three reasons. Firstly, due to larger maximal cardiac output. Secondly, the redistribution of blood to muscle from non active areas and thirdly, an increase in cross sectional areas of the large and small arteries and vein as well as an increase in microcirculation (123).
Pulmonary functions also improve as a result of aerobic training. Increased breathing volumes accompany improvements in VO2max. Higher maximum ventilation results from increases in tidal volume and breathing rates. During submaximal exercise, trained subjects ventilate less than they do before training. This adaptation is helpful in prolonged exercise because improved ventilatory economy means more oxygen availability to active muscles. Interval swim training for 10 weeks was found to increase the VO2max. by 11% (107). In another study Fleck et al observed that resistance training increase the VO2max. (45). Extensive metabolic adaptations also occur due to training which is characterized by increase in the number and size of the mitochondria, increase in the level of aerobic system enzymes (74), increased capability of the muscle to mobilize, deliver and oxidize lipid molecules (34, 178), improvement in fatty acid β-oxidation, increased capacity to oxidize carbohydrates (74) and hypertrophy of muscle fiber.

The effect of training on anaerobic system changes is also well documented. Anaerobic system changes is characterized by increase in resting levels of anaerobic substrates (104), increase in quantity and activity of key enzymes that control the anaerobic phase of glucose breakdown (77), increase in the capacity for generating high levels of blood lactate during all out exercise.

Other adaptations in the body associated with exercise training include reduction in body fat, accompanying with increase in lean body mass, improvement in thermoregulatory efficiency (129), reduction in anxiety, neuroticism and improvement in mood, self concept and general perception of personal worth.

The effect of yoga training on different physiological parameters is also well documented (84, 207, 255). Cardiovascular, respiratory, and neurological functions improve after yoga training (134, 140, 142, 174, 208, 209, 211, 228, 267). Surya Namaskar (SN) is a very popular form of yogic practices being performed by many individuals as a routine physical exercise regimen. The practice of SN involves many of the muscles, joints of the body. During its
practice stretching of the different muscles of the body take place. Till date no report is available regarding the longitudinal effects of SN training of different physiological parameters. So the present study was undertaken.

8.2 Aim

The Present study was aimed to observe the effect of training (one year) on physiological responses in Surya Namaskar at three different phases.

8.3 Material and methods

9 normal healthy male volunteers were chosen for the present study. Subjects underwent training in SN daily in the morning for 6 days in a week. They practiced one round of SN in 3min. 40 second for the first 10 days from the commencement of the training. They then gradually increased the number of rounds by two every after five days until the attainment of 10 rounds. 1st, 2nd and 3rd phase of the study was conducted exactly after 3 months, 6months and 11 months i.e. at the beginning of the 4th month, 7th month and 12th month respectively. Different cardiorespiratory parameters as mentioned in the earlier sections were recorded during the practice of SN at three different phases. Different parameters were then compared amongst three different phases statistically by using paired two tail t-test.

8.4 Result

The training effects on different cardiorespiratory parameters while performing SN at three different phases were shown from the Figures from Figure 36 to Figure 45. Effects are shown separately in 12 Postures of SN.

8.4.1 Training effects on VO₂

VO₂ significantly decreased (P<0.05) from first phase to second phase only in the 8th posture and rest of the postures did not show any significant difference. It significantly decreased from second phase to third phase in the 3rd, 7th (P<0.05) and 6th, 12th (P<0.01) and 8th, 9th, 10th (P<0.001) postures respectively. When first phase was compared with the third phase VO₂ reduced
significantly at P<0.05, P<0.01 and P<0.001 level in 1st, 2nd, 9th, 10th and 3rd, 4th, 7th, 12th and 8th postures respectively.

8.4.2 Training effects on HR

HR increased significantly (P<0.001) from first phase to second phase only in the 1st posture and rest of the postures did not show any significant difference. When second phase was compared with the third phase HR was found to be significantly reduced in the 3rd posture (P<0.05) and 1st, 9th, 10th (P<0.01) postures and 7th, 8th (P<0.001) postures. When first phase was compared with the third phase, HR reduced significantly (P<0.001) only in the 3rd and 7th postures.

8.4.3 Training effects on O$_2$P

O$_2$P decreased significantly from first phase to second phase in 1st, 4th and 8th posture and the significant level was P<0.01 and P<0.001 respectively. When 2nd phase was compared with the 3rd phase it was found that the O$_2$P to be significantly decreased in 8th and 10th posture at P<0.01 and P<0.05 level respectively. When 1st phase was compared with the 3rd phase it was seen that the O$_2$P significantly decreased in 1st, 2nd, 3rd, 4th, 9th, 11th, 12th posture at P<0.05 level and it also decreased significantly (P<0.001) in the 8th posture.

8.4.4 Training effects on V$_E$

V$_E$ did not change significantly from 1st to 2nd and from 2nd to 3rd phase in all the postures except it decreased in 3rd posture (P<0.01), 6th posture (P<0.05), 10th posture (P<0.05), from 2nd to 3rd phase. When 1st phase was compared to the 3rd phase V$_E$ reduced significantly (P<0.05), only in the 8th posture.

8.4.5 Training effects on f$_R$

f$_R$ did not change significantly from 1st phase to 2nd phase in all the postures except decreased in the 4th posture (P<0.05). f$_R$ did not change from
2\textsuperscript{nd} to 3\textsuperscript{rd} phase and when 1\textsuperscript{st} phase was compared with the 3\textsuperscript{rd} phase it showed significant increase only in the 7\textsuperscript{th} posture (P<0.05).

8.4.6 Training effects on $V_T$

$V_T$ significantly decreased from 1\textsuperscript{st} to 2\textsuperscript{nd} phase (P<0.05) only in 9\textsuperscript{th} posture. It decreased significantly in 1\textsuperscript{st} posture (P<0.01) only at the 3\textsuperscript{rd} phase as compared to 2\textsuperscript{nd} phase. $V_T$ decreased significantly in the 7\textsuperscript{th} posture and 9\textsuperscript{th} posture (P<0.05) if the 3\textsuperscript{rd} phase as compared to 1\textsuperscript{st} phase.

8.4.7 Training effects on $EQO_2$

In the comparison between 1\textsuperscript{st} phase and 2\textsuperscript{nd} phase there was significant increase (P<0.05) in $EQO_2$ in the 8\textsuperscript{th}, 11\textsuperscript{th} and 12\textsuperscript{th} postures. When 2\textsuperscript{nd} phase was compared with 3\textsuperscript{rd} phase $EQO_2$ showed a significant increase in the 1\textsuperscript{st}, 7\textsuperscript{th}, 9\textsuperscript{th}, 10\textsuperscript{th} posture (P<0.01). It was also significantly higher in the 2\textsuperscript{nd}, 3\textsuperscript{rd} and 8\textsuperscript{th} postures (P<0.05) at the 3\textsuperscript{rd} phase with respect to the 1\textsuperscript{st} phase. It also significantly increased at the 3\textsuperscript{rd} phase in the 1\textsuperscript{st}, 11\textsuperscript{th} posture (P<0.05).

8.4.8 Training effects on $EQCO_2$

In the comparison between 1\textsuperscript{st} phase and 2\textsuperscript{nd} phase there was significant increase in $EQCO_2$ in the 2\textsuperscript{nd}, 5\textsuperscript{th} and 7\textsuperscript{th} postures (P<0.05), 6\textsuperscript{th}, 8\textsuperscript{th} and 10\textsuperscript{th} postures (P<0.01), 11\textsuperscript{th} and 12\textsuperscript{th} postures (P<0.001). When 2\textsuperscript{nd} phase was compared with the 3\textsuperscript{rd} phase $EQCO_2$ showed only significantly higher value in the 7\textsuperscript{th} posture (P<0.001). It was also significantly higher in the 5\textsuperscript{th} posture (P<0.05), 1\textsuperscript{st}, 3\textsuperscript{rd} and 6\textsuperscript{th} postures (P<0.01) and 7\textsuperscript{th}, 8\textsuperscript{th}, 10\textsuperscript{th}, 11\textsuperscript{th} and 12\textsuperscript{th} postures (P<0.001) at the 3\textsuperscript{rd} phase with respect to the 1\textsuperscript{st} phase.

8.4.9 Training effects on $VCO_2$

When 1\textsuperscript{st} phase was compared with the 2\textsuperscript{nd} phase $VCO_2$ was significantly reduced in 4\textsuperscript{th}, 8\textsuperscript{th} and 11\textsuperscript{th} posture (P<0.05) and in 9\textsuperscript{th}, 12\textsuperscript{th} posture (P<0.01). When 2\textsuperscript{nd} phase was compared with the 3\textsuperscript{rd} phase $VCO_2$ significantly decreased in the 3\textsuperscript{rd}, 9\textsuperscript{th} and 10\textsuperscript{th} posture (P<0.01) and in 8\textsuperscript{th} posture (P<0.05). When 1\textsuperscript{st} phase was compared with the 3\textsuperscript{rd} phase $VCO_2$ significantly decreased in 1\textsuperscript{st}, 2\textsuperscript{nd},
4th, 7th and 11th posture, all are significant at \( P<0.05 \) level and in the 3rd, 6th, 9th, 10th and 12th posture (\( P<0.01 \)) and in the 8th posture (\( P<0.001 \)).

### 8.4.10 Training effects on \( \text{VO}_2/\text{kg} \)

When \( \text{O}_2 \) consumption was expressed per kg of the body weight it was seen that \( \text{VO}_2/\text{kg} \) reduced significantly (\( P<0.05 \)) in 8th and 12th posture from 1st to 2nd phase. When 2nd phase was compared with the 3rd phase 3rd, 7th posture (\( P<0.01 \)) 6th, 12th posture (\( P<0.05 \)) and 8th, 9th, 10th (\( P<0.001 \)) posture showed significant fall in VCO\(_2\) in the 3rd phase. When 1st phase was compared with the 3rd phase 2nd, 9th, 10th (\( P<0.05 \)) and 3rd, 4th, 7th, 12th (\( P<0.01 \)) and 8th posture (\( P<0.001 \)) showed significant fall in VCO\(_2\) in the 3rd phase.

### 8.5 Discussion

The significantly reduced \( \text{VO}_2 \) at 4th, 7th and 12th months of training in different postures of SN is due to conditioning effect. When 1st phase was compared with the 2nd phase \( \text{VO}_2 \) reduced significantly only in one posture of SN but when 1st phase was compared with the 3rd phase \( \text{VO}_2 \) reduced in nine postures of SN. The better conditioning of different muscles during Asanas has helped the trainees to achieve the particular postures by economizing the energy costs as it is observed in any training programme in conventional type of exercise (73). Same is also evident in the present study. In case of HR the optimum level of conditioning effect was found in the 3rd phase following 12 months of training. Decrease in HR following training is evident in many studies (65, 86, 230). In case of \( \text{O}_2 \)P similar result was found as that of HR. When the respiratory parameters like \( V_E \), \( f_R \) and \( V_T \) were considered, it was found that it was not decreased in the 2nd phase following 6 months of training. \( V_E \), \( f_R \) and \( V_T \) significantly reduced in 3rd phase either in one or two postures following 12 months of training. From the above findings it appeared that respiratory parameters showed delayed conditioning and reduced gradually in different phases which is supported in one of our studies related to yoga (173). Higher cardiovascular conditioning was seen in trainees in 3rd phase unlike respiratory parameters.
Amongst the various cardiovascular parameters carbon dioxide output showed the highest level of conditioning in yoga training. Carbon dioxide output decreased significantly in the 3rd phase in 11 postures following 11 months of training. The reduction in carbon dioxide output must have been achieved by gradual decrease in carbon dioxide production metabolically inside the cell following yoga training. This also happens following conventional type of physical exercise training. Gradual reductions in ventilation in the 3rd phase of training indicate improvement in pulmonary function following Yoga training. The reduction in ventilation also occurs in the trained subjects during submaximal exercise following aerobic exercise training (118). Studies by Nayar et al also showed that there was an improvement in cardiorespiratory functions in NDA cadet after one year of Yoga training (14C).

Ventilatory equivalent for oxygen and carbon dioxide increased in trainees in the 2nd and 3rd phase as compared to the 1st phase. Since EQO₂ and EQCO₂ is the ratio of ventilation with respect to oxygen and carbon dioxide respectively, the training effects on the ventilation, oxygen consumption and carbon dioxide output is reflected on EQO₂ and EQCO₂. \( \text{VO}_2 \) and \( \text{VCO}_2 \) were reduced significantly in different phases of the training. This is the reason for the higher value of EQO₂ and EqCO₂ in the 2nd and 3rd phase as compared to the 1st phase. Reductions of \( V_E \) also occur in the present study following training. But this reduction is not statistically significant in all the cases.

Thus it may be inferred from the foregoing discussion that cardiovascular parameters get conditioned faster than respiratory parameters, which showed, delayed conditioning.
Summary

The effect of Yogic training was observed on various cardiorespiratory parameters in Yoga trainees at three different phases of the training at the 4\(^{th}\) (1\(^{st}\) phase), 7\(^{th}\) (2\(^{nd}\) phase) and 12\(^{th}\) (3\(^{rd}\) phase) month of the training. It was found out that VO\(_2\) decreased significantly from 1\(^{st}\) phase to 2\(^{nd}\) phase only in the 8\(^{th}\) posture. It decreased significantly from 2\(^{nd}\) phase to 3\(^{rd}\) phase in the 3\(^{rd}\), 6\(^{th}\), 7\(^{th}\), 8\(^{th}\), 9\(^{th}\), 10\(^{th}\) and 12\(^{th}\) postures respectively. When 1\(^{st}\) phase was compared with the 3\(^{rd}\) phase, VO\(_2\) was reduced significantly in 1\(^{st}\), 2\(^{nd}\), 3\(^{rd}\), 4\(^{th}\), 7\(^{th}\), 8\(^{th}\), 9\(^{th}\), 10\(^{th}\) and 12\(^{th}\) postures respectively. HR increased significantly from 1\(^{st}\) phase to 2\(^{nd}\) phase only in the 1\(^{st}\) posture. When 2\(^{nd}\) phase was compared with the 3\(^{rd}\) phase, HR was found to be reduced significantly in the 1\(^{st}\), 3\(^{rd}\), 7\(^{th}\), 8\(^{th}\), 9\(^{th}\) and 10\(^{th}\) postures. When 1\(^{st}\) phase was compared with the 3\(^{rd}\) phase, HR reduced significantly only in the 3\(^{rd}\) and 7\(^{th}\) postures. VE decreased in 3\(^{rd}\) posture, 6\(^{th}\) posture and 10\(^{th}\) posture from 2\(^{nd}\) to 3\(^{rd}\) phase. When 1\(^{st}\) phase was compared with the 3\(^{rd}\) phase, VE reduced significantly only in the 8\(^{th}\) posture. f\(_{R}\) was reduced in the 4\(^{th}\) posture from 1\(^{st}\) phase to 2\(^{nd}\) phase. f\(_{R}\) increased significant only in the 7\(^{th}\) posture when 1\(^{st}\) phase was compared with the 3\(^{rd}\) phase. VT decreased significantly from 1\(^{st}\) to 2\(^{nd}\) phase only in 9\(^{th}\) posture. It decreased significantly in 1\(^{st}\) posture only when the 3\(^{rd}\) phase was compared with the 2\(^{nd}\) phase. It decreased significantly in the 7\(^{th}\) posture and 9\(^{th}\) posture when the 3\(^{rd}\) phase was compared with the 1\(^{st}\) phase. VCO\(_2\) was reduced in some of the postures of SN at different phases of the training.

As in other type of exercises the effect of physical conditioning due to training is also observed in SN. The overall cardiorespiratory data showed that the effect of conditioning due to training may be also achieved in SN as found in other types of exercise. It appeared that respiratory parameters showed delayed conditioning whereas cardiovascular parameters showed quick conditioning as a result of Yogic training.
Figure 36. Oxygen consumption (millilitre per minute) in twelve postures of Surya Namaskar in Yoga trainees and at three different phases of the training. Values are mean ± sem.

**/+ P<0.05
**/+ P<0.01
**/+ P<0.001

Comparison between 1st and 2nd phase respectively
Figure 37. Heart rate (beats per minute) in twelve postures of Surya Namaskar in Yoga trainees at three different phases of the training. Values are mean ± sem.

*/+ Comparison between 1st and 2nd phase respectively

*/+ P<0.05

**/+ P<0.01

+++ P<0.001
Figure 38. Oxygen pulse (ml. per beat) in twelve postures of Surya Namaskar in Yoga trainees at three different phases of the training. Values are mean ± sem.

*+/+ Comparison between 1st and 2nd phase respectively

*+/+ P<0.05

*/++ P<0.01

*/+++ P<0.001
Figure 39. Ventilation (litre per minute) in twelve postures of Surya Namaskar in Yoga trainees at three different phases of the training. Values are mean ± sem.

/*+ Comparison between 1st and 2nd phase respectively
++ P<0.05
++/+ P<0.01
+++ P<0.001
Figure 40. Breathing frequency (breaths per minute) in twelve postures of Surya Namaskar in Yoga trainees at three different phases of the training. Values are mean ± sem.

*+/ Comparison between 1st and 2nd phase respectively

*/+ P<0.05
**+/++ P<0.01
****+/+++ P<0.001
Figure 41. Tidal volume (litre per breath) in twelve postures of Surya Namaskar in Yoga trainees at three different phases of the training. Values are mean ± sem.

*+/+ Comparison between 1st and 2nd phase respectively

*/+ P<0.05

**/+ P<0.01

****/+ P<0.001
Figure 42. Carbon dioxide output (litre per minute) in twelve postures of Surya Namaskar in Yoga trainees at three different phases of the training. Values are mean ± sem.

*/*+ Comparison between 1st and 2nd phase respectively

*/*+ P<0.05

**/*++ P<0.01

***/*+++ P<0.001
Figure 43. Ventilatory equivalent for oxygen in twelve postures of Surya Namaskar in Yoga trainees at three different phases of the training. Values are mean ± sem.

* Comparison between 1st and 2nd phase respectively
**/+ P<0.05
**/+ P<0.01
**/+ P<0.001
Figure 44. Ventilatory equivalent for carbon dioxide output in twelve postures of Surya Namaskar in Yoga trainees at three different phases of the training. Values are mean ± sem.

*/+ Comparison between 1st and 2nd phase respectively

*/+ P<0.05
***/++ P<0.01
***/+++ P<0.001
Figure 45. Relative values of oxygen consumption (ml. per minute per kg.) in twelve postures of Surya Namaskar in Yoga trainees at three different phases of the training. Values are mean ± sem.

*/+ Comparison between 1st and 2nd phase respectively

*/+ P<0.05

**/+ P<0.01

***/+++ P<0.001