Section IV

General methodology
4. General methodology

4.1 Subjects

40 soldiers were taken from a regiment of the Indian Army for the present study. They were divided into two equal groups. One group (Yoga group n=20) was imparted training in SN along with other Yogic Asanas (Yogic physical exercises), Pranayamas (Yogic breathing exercises) and Meditation (Yogic concentration) for eleven months. Other group (control group n=20) used to participate in the physical training programme daily for one hour throughout the study period. All the subjects were free from any clinical disorders and had no prior experience of practicing Surya Namaskar. Subjects being from the army had uniform pattern of daily routine activity schedule and used to have diet supplying 3700 kcal. of energy (approximately) from a common mess. They gave their informed consent to participate in the study and the ethical committee of the Institute approved the test protocol. Before the commencement of the study all the subjects returned from their annual leave of two months. The age, height and body weight of the subjects are given in the Table 1.

Other two groups of subjects namely yoga proficient (who were practicing SN for more than 4 years) and Yoga Semi-Proficient (who were having the experience of practicing SN for 2 to 4 years) also participated in the present study. The number of proficient and Semi-Proficient was 10 in each. Another group of 20 subjects also participated in the present study. They were designated as Yoga Instructors. Due to some unavoidable reason 3 subjects were dropped out. Final recordings were made on 17 subjects only. They were practicing Yoga for more than 10 years. Their age, height and body weight are also given in the Table 1.

A group of 9 trainees did Yoga for a year and their recordings were taken in the 4th, 7th and 12th month of the training. Their age was (22.2±2.4, 22.5±1.9 and 23. ±1.7 years), height was (171.9±4.5, 171.9±4.5 and 171.9±4.5 cms) and body weight was (61.9±3.4, 61.5±4.5 and 60.2±3.4 kg).

4.2 Practice of Surya Namaskar

Yoga group underwent training in Surya Namaskar daily in the morning (6A.M.) with an empty stomach under the supervision of a qualified yoga instructor for 6 days in a week for 11 months. They used to have their dinner at 8 P.M. daily from a common mess and in the morning they were not allowed to take anything before practice. They got trained to perform all the twelve postures in 3 min. and 40 sec. They used to practice 10-12 rounds.
of Surya Namaskar. This was done with an aim to keep the consistency in the practice of Surya Namaskar. The practices of different postures are described below briefly.

4.2.1 1st Posture 'Prayer pose' or 'Pranamasana'

The subject stood erect with the feet together or slightly apart. Both the palms were placed together in front of the chest with normal breathing. At the end of the posture it was exhaled fully. The duration of the posture was 10 sec.

In this posture adduction of shoulder joint, flexion of the elbow joint and pronation of the forearm has taken place. During this standing posture all the antigravity muscles are working.

Adduction of shoulder joint has brought about by sternocostal head of pectoralis major, coracobrachialis and Lateral deltoid muscles. Flexion of the elbow joint has brought about by Biceps brachii, brachialis and brachioradialis muscles. Pronation of the fore arm is brought about by pronator quadratus and pronator teres muscles.

4.2.2 2nd Posture 'Raised arms pose' or 'Hasta Uttanasana'.

Both the arms were raised and stretched above the head from the 1st position. The head, arms and upper trunk was bent backward as far back as possible without any discomfort. Deep inspiration was taken while raising the arm. The duration of the posture was 20 sec.

In this posture extension of the neck, back and wrist and flexion of shoulder has taken place. Here extension of the fingers also takes place. Elevation of scapula in this posture is brought about by upper part of the trapezius and levator scapulae muscles. Sternocleidomastoid and trapezius extends the neck.

Posterior deltoid, infraspinatus, teres minor, teres major, latissimus dorsi extends shoulder. Extensor carpi radialis longus, extensor carpi radialis brevis, extensor carpi ulnaris extends hand at the wrist joint. Extension of the back is brought about by the contraction of the trapezius and latissimus dorsi. Extensor digitorum extends the fingers. Extensor digitii minimi helps in the extension of metacarpophalangeal joints of little fingers. Extensor pollicis longus helps in the extension of distal phalanx of the thumb.
4.2.3 3rd Posture 'Hand to foot pose' or 'Padahastasana'

In a continuous movement with the earlier posture body was bent forward from the hips and hands were brought to the floor on either side of the feet and head was kept as close as possible to the knees. The legs were kept straight. The breath was exhaled while moving into the posture. The duration of the posture was 30 second.

In this posture flexion of the neck joint, flexion at the shoulder joint, extension at the elbow joint, wrist joint and metacarpophalangeal joints of five digits. Here flexion of the back also takes place. Sternocleidomastoid and trapezius muscles bring about flexion of the neck. anterior deltoid, clavicular head and sternocostal head of pectoralis major and coracobrachialis group of muscles bring about flexion of the shoulder joint.

Extension of the elbow joint, wrist joint and finger joints is brought about by the same group of muscles which are in action in the second posture for the extension of the elbow joint, wrist joint and finger joints.

In the 1st, 2nd and 3rd posture the lower limbs are in the attitude of extension at hip, knee and neutral position at the ankle joint. Extension of the hip joint has brought about by gluteus maximus, aductor magnus and hamstring group of muscles. Quadriceps femoris, rectus femoris, vastus lateralis, vastus intermedius and vastus medialis help in the extension of the knee.

4.2.4 4th Posture 'Equestrian pose' or 'Ashwasanchalanasana'

Leg was extended backwards as far as possible from the earlier posture. Both the hands were raised and stretched above the head. The right toes and knee was touched to the floor. The pelvis was brought forward and the spine was arched and the inner gaze was directed upward to the eyebrow centre. The breath was inhaled while raising the arms. The duration of the posture was 30 second.

4.2.5 5th Posture 'Equestrian pose' or 'Ashwasanchalanasana'

This posture was same as the 4th posture. The only difference was that here right knee was bent and the left leg was extended backwards as far as possible. Deep inspiration was taken while raising the arms. The duration of the posture was 30 second.
In the 4th and 5th posture, extension of the neck, elevation of the scapula, extension of the back, shoulder, wrist and fingers take place in the upper limb. The muscles involved are similar to those used in the 2nd posture.

In the lower limb extension at the hip joint, knee joint in the stretched leg take place. Dorsiflexion at the ankle joint occurs in the stretched leg. On the other leg flexion at the hip joint and knee joint occur. The ankle joint in this leg is neither in the attitude of dorsiflexion nor plantar flexion.

Extension of the hip joint and knee joint is brought about by the muscle groups those are involved in the extension of these joints in the 1st, 2nd and 3rd postures as mentioned earlier.

Dorsiflexion at the ankle joint in the stretched leg occurs by the action of tibialis anterior, extensor digitorum longus, extensor hallucis longus and peroneus tertius group of muscles.

Psoas major, iliacus, pectineus, rectus femoris, adductor longus and sartorius group of muscles in the other leg bring about flexion of the hip joint. Flexion of the knee joint in this leg is brought about by semitendinosus, semimembranosus, biceps femoris and gastrocnemius group of muscles.

4.2.6 6th Posture 'Mountain Pose' or 'Parvatasana'

Right foot was brought back and was placed beside the left foot. The buttock was raised and head was lowered between the arms so that the body formed a triangle with the floor. This movement was performed on expiration. The duration of the posture was 5 second.

This posture is characterized by the extension of the fingers, extension of the wrist joint, elbow joint and flexion of the shoulder joint in the upper limb. The muscles involved in these types of movements are mentioned earlier. In the lower limb flexion at the hip joint, extension at the knee joint and dorsiflexion at the ankle joint occur.
4.2.7 7th Posture 'Salutation with eight limbs' or 'Ashtangaamaskara'

The knees were bent to the floor and the chest and chin was brought to the floor keeping the buttocks elevated. The hand, chin chest, knees and toes were touched to the floor and the spine was arched. The breath was retained in exhalation from the earlier position. The duration of the posture was 25 second.

This posture is characterized by the semiextension of the neck joint, extension of the shoulder joint, flexion of the elbow joint, extension of the wrist joint and extension of the fingers in the upper limb. Here extension of the back also takes place.

This posture has shown partial flexion at the hip joint, partial flexion at the knee joint and dorsiflexion of the ankle joint in the lower limb. Muscles concerned for these movements are mentioned earlier.

4.2.8 8th Posture 'Serpent Pose' or 'Bhujangasana'

The hip was lowered and the chest was pushed forward and upward with the arms until the spine is fully arched. The head was bent back, the legs and lower abdomen remained on the floor and the arms supported the trunk. The breath was inhaled while moving forward and upward into position. The total duration of the posture was 30 second.

Extension of the neck joint, extension of the back, flexion of the shoulder joint, extension of the elbow joint, extension of the wrist joint and extension of the fingers in the upper limb characterize this posture.

In the lower limb extension at the hip, extension at the knee joint and dorsiflexion of the ankle joint has occurred. Muscles involved for these movements are mentioned earlier.

4.2.9 9th Posture 'Salutation with eight limbs' or 'Ashtangaamaskara'

This posture is the repetition of the 7th posture. Only difference from the 7th posture is that duration of the stay in this posture was very short (3 second).

4.2.10 10th Posture

This posture is the repetition of the 6th posture. Duration of this posture was 7 second.
4.2.11 11th Posture

This posture is repetition of the 3rd posture. Breath was exhaled while moving into the position. The duration of the posture was 20 second.

4.2.12 12th Posture

This is same as the 1st posture. The breath was inhaled while moving into the position. After coming into the final posture the breath was taken normally. The duration of the posture was 10 second.

The different postures of the Surya Namaskar practice were presented in the Figure 1. Duration of stay in each posture and the pattern of breathing in SN in case of trainees. Proficient and Semi-Proficient are given in the Table 2. The time duration for performing Surya Namaskar by Yoga instructors were given in Section 5.

4.3 Control group

Control group used to participate in the physical training programme as per the army schedule. The total duration of the physical training schedule was 1 hour and consisted of slow running up to 4 km. (10 minutes), pull up (5 minutes) and games (15 minutes).

4.4 Different phases of the study

Yoga group used to practice Surya Namaskar daily in the morning for 11 months as stated earlier. After 3 months of training first phase of the study was conducted in the laboratory i.e at the beginning of the 4th month. After 6 months and 11 months of training 2nd and 3rd phase of the study was conducted in the laboratory at the beginning of 7th month and 12th month respectively.

4.5 Parameters studied

Before commencement of the SN training basic physiological recordings like resting heart rate (HR), Oxygen consumption (VO₂), carbon dioxide elimination (VCO₂), ventilation (VE), breathing frequency (fR), tidal volume (VT), ventilatory equivalent for oxygen (EQO₂), Ventilatory equivalent for carbon dioxide (EQCO₂), Oxygen pulse (O₂P), blood pressure (BP), oral temperature (TO), and blood lactate of yoga and control group were recorded. Similar basal recordings were also taken during 2nd and 3rd phase of the study (before performing Surya Namaskar) on yogas well as on control group. Basal resting
parameters of Yoga Proficient and Semi-Proficient are also measured and shown in Table 3.

Recordings of all the parameters mentioned above except blood lactate and T_or were done during the actual practice of SN in the 1st, 2nd and 3rd phase of the study. Similar recordings were taken on yoga Proficient and Semi-Proficient. Yoga group performed incremental load maximum exhaustive exercise on a bicycle ergometer for determining their maximal oxygen consumption (VO_2max). The derived parameters such as, O_2P was calculated by dividing VO_2 (ml./min.) / HR (beats/min.). EQO_2 and EQCO_2 is the ratio of VE (lit./min.), VO_2 (lit./min.) and VE (lit./min.), VCO_2 (lit./min.) respectively. Relative values of VO_2 was found out by dividing VO_2 (ml./min.) by body mass (kg.) of the subjects. Oral temperature was measured by degree Celsius. Blood pressure was expressed as mmHg. Blood lactic acid was expressed as mmol/L. of the blood.

4.6 Equipment Used

The equipment used in the present study were as follows:-

4.6.1 Computerised oxygen consumption measurement system (Oxycon Champion, Erich Jaeger, Germany).

4.6.2 Electrically braked Bicycle Ergometer (ergometrics er900, ergoline, GmbH & Co KG Medical Measuring Systems, Germany).

4.6.3 Telemetric heart rate monitor (Sports tester, Polar Electro, Finland).

4.6.4 Non invasive blood pressures measurement system (Electrosphygmo-manometer) - Propaq, USA.

4.6.5 Oral temperature recorded by Yellow Springs, USA (YSI) precalibrated thermister probe.

4.6.6 Blood lactic acid was measured by Lactate analyzer (1500, YSI, USA).
4.6.1 Oxygen consumption measurement system

The arrangements for recording oxygen consumption and other cardiorespiratory parameters were shown in different Figures from Figure 2 to Figure 5. Oxygen consumption measurement system mainly comprised of paramagnetic oxygen analyzer and infrared CO$_2$ analyzer. Subjects were put on a special type of facemask with which an opto-electronic transducer was attached. This transducer is basically a volume transducer that senses the two basic respiratory parameters e.g. breathing frequency and tidal volume. A tube called twin tube was connected to a small aperture of the transducer. Twin tube basically consists of two very thin long tube joined together from the transducer to the analyzer. The water vapour of the expired air gets condensed on the inner surface of the twin tube. Condensed water gets collected in a small container of the instrument before the expired gas sample passed through the analyzers. The system sucks a small amount of the sample from the expired air through the twin tube by means of a pump and sends the dry gas sample to the analyzer for O$_2$ and CO$_2$ analysis. The sampling rate of the analyzer was 200 Hz and intrabreath expired air gas sample was analyzed by this particular system for the present design of the study.

4.6.2 Bicycle Ergometer

The bicycle ergometer was shown in the Figure 6. In Electrically braked bicycle ergometer resistance was provided by means of electromagnetic braking force produced by direct current generator activated from an outside electrical source. Here one watt equals to 6.12 kg.m./min.

4.6.3 Heart rate measurement system

The different components of the telemetric heart rate monitor and the recording arrangement of it were shown in the Figure 7 and the Figure 8. Heart rate was measured by Telemetric heart rate monitor. The subject wore a special type of chest band inside which sensor was present which detects the heart rate signal from the surface of the chest. Chest band was made moistened by applying little water. One monitor in the form of a wristwatch was put over the subject’s left hand. The heart rate monitor saved the beat-to-beat heart rate data in the memory and later on print out was taken after downloading into a computer.
4.6.4 Blood pressure measurement system

The Electrosphygmomanometer was shown in the Figure 9. An arm cuff tied over the left arm measured blood pressure. One oscilometric sensor was present inside the cuff and it was placed in the arm in such a manner that sensor could feel the brachial arterial pulse. Cuff was inflated by means of a pump and the sensor automatically sensed the systolic blood pressure when the blood just started flowing through the obliterated vessels and giving a ‘bip’ sound indicated it. When the ‘bip’ sound is no longer heard the pressure head indicated the diastolic pressure. Systolic and diastolic pressure value was displayed in the propaq monitor and later on print out was taken. Mean blood pressure was calculated automatically by the instrument with the help of a software by using the standardised formula for the mean blood pressure i.e. mean blood pressure = 1/3 of pulse pressure + diastolic pressure. The system used some correction factor while determining the mean blood pressure by considering the dead space value of the long measuring tube from the cuff to the instrument.

4.6.5 Recording of Oral temperature

Oral temperature probe for recording the oral temperature was shown in the Figure 10. Oral temperature was monitored by means of a polygraph with the help of a thermister probe from YSI, USA. The probe was put under the tongue for 5 min. before readings were noted down from digitally displayed monitor.

4.6.7 Blood lactic acid measurement

Blood lactic acid was measured by taking arterial blood samples by means of finger prick and later on analyzed by the lactate analyzer (YSI).

4.7 Statistical analysis

Statistical analyses of the various data were done by using the statistical package of Microsoft excel program. The name of the specific statistical test employed was mentioned in each section individually.
Table 1. Physical characteristics of the subjects of Yoga group, control group at different phases of the training and that of Yoga Proficient, Semi-Proficient and Yoga Instructors. [Values are mean ± s.d.]

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameters</th>
<th>Yoga Group</th>
<th>Control Group</th>
<th>Proficient (n=10)</th>
<th>Semi-Proficient (n=10)</th>
<th>Yoga Instructors (n=17)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I (n=20)</td>
<td>II (n=20)</td>
<td>III (n=20)</td>
<td>I (n=20)</td>
<td>II (n=20)</td>
</tr>
<tr>
<td>1</td>
<td>Age (Years)</td>
<td>22.3 ± 1.31</td>
<td>22.6 ± 1.46</td>
<td>23.4 ± 1.42</td>
<td>22.4 ± 1.22</td>
<td>22.7 ± 1.20</td>
</tr>
<tr>
<td>2</td>
<td>Height (centimeters)</td>
<td>172.8 ± 4.60</td>
<td>172.8 ± 4.53</td>
<td>172.6 ± 3.96</td>
<td>171.1 ± 3.37</td>
<td>171.1 ± 3.37</td>
</tr>
<tr>
<td>3</td>
<td>Body Weight (kilogram)</td>
<td>62.5 ± 4.10</td>
<td>62.5 ± 4.10</td>
<td>61.8 ± 3.78</td>
<td>60.7 ± 5.50</td>
<td>61.2 ± 5.05</td>
</tr>
</tbody>
</table>
Table 2. Duration of stay in each posture and Breathing pattern in *Surya Namaskar*.

<table>
<thead>
<tr>
<th>Posture</th>
<th>Time duration (Seconds)</th>
<th>Breathing pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>Normal breathing</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>Deep inspiration</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>Slow Expiration, Normal breathing</td>
</tr>
<tr>
<td>4*</td>
<td>30</td>
<td>Deep Inspiration</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>Deep Inspiration</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>Breath hold at inspiration</td>
</tr>
<tr>
<td>7</td>
<td>25</td>
<td>Breath hold at expiration</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>Deep Inspiration followed by normal breathing</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>Breath hold at expiration</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>Breath hold at inspiration</td>
</tr>
<tr>
<td>11</td>
<td>20</td>
<td>Slow expiration, normal breathing</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>Normal breathing</td>
</tr>
</tbody>
</table>

* There is a transition phase while changing from 4th to 5th posture
Table 3. Basal resting parameters in yoga, control group (I, II, III Phase) and in yoga Proficient, Semi-Proficient. (Values are mean ± s.d.)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Yoga Group</th>
<th>Control Group</th>
<th>Proficient</th>
<th>Semi-proficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>I</td>
</tr>
<tr>
<td>Heart rate (beats per minute)</td>
<td>63.2± 6.89</td>
<td>61.1± 3.73</td>
<td>61.1± 8.23</td>
<td>66.4± 7.03</td>
</tr>
<tr>
<td>Oxygen consumption (litre/min)</td>
<td>0.249± 0.089</td>
<td>0.257± 0.110</td>
<td>0.232± 0.123</td>
<td>0.276± 0.091</td>
</tr>
<tr>
<td>Carbondioxide output (litre/min)</td>
<td>0.232± 0.088</td>
<td>0.229± 0.156</td>
<td>0.215± 0.125</td>
<td>0.201± 0.076</td>
</tr>
<tr>
<td>Ventilation (litre/min)</td>
<td>9.2± 1.8</td>
<td>9.1± 1.8</td>
<td>9.4± 1.7</td>
<td>8.9± 1.0</td>
</tr>
<tr>
<td>Breathing frequency (breaths/min)</td>
<td>17.9± 4.5</td>
<td>17.2± 3.3</td>
<td>17.0± 3.0</td>
<td>18.0± 4.6</td>
</tr>
<tr>
<td>Tidal Volume (litre/breath)</td>
<td>0.543± 0.04</td>
<td>0.601± 0.07</td>
<td>0.610± 0.10</td>
<td>0.523± 0.03</td>
</tr>
<tr>
<td>Oxygen Pulse (ml/beat)</td>
<td>3.98± 0.69</td>
<td>4.26± 0.56</td>
<td>3.87± 0.32</td>
<td>4.23± 0.89</td>
</tr>
<tr>
<td>Ventilatory equivalent for oxygen</td>
<td>36.7± 6.04</td>
<td>35.0± 4.39</td>
<td>40.01± 2.05</td>
<td>31.7± 3.95</td>
</tr>
<tr>
<td>Ventilatory equivalent for carbon dioxide</td>
<td>38.8± 7.04</td>
<td>39.5± 1.95</td>
<td>42.8± 2.01</td>
<td>44.3± 3.05</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>110.8± 8.74</td>
<td>113.4± 7.95</td>
<td>111.5± 8.34</td>
<td>113.0± 8.13</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>66.9± 8.59</td>
<td>63.6± 6.04</td>
<td>65.6± 4.43</td>
<td>63.1± 9.89</td>
</tr>
<tr>
<td>Mean blood pressure (mmHg)</td>
<td>81.6± 6.62</td>
<td>80.3± 6.26</td>
<td>80.9± 5.19</td>
<td>81.0± 8.51</td>
</tr>
<tr>
<td>Oral temperature (°C)</td>
<td>37.0± 0.155</td>
<td>36.9± 0.124</td>
<td>36.8± 0.147</td>
<td>37.1± 0.272</td>
</tr>
<tr>
<td>Blood lactic acid (mmol/lit)</td>
<td>1.95± 0.29</td>
<td>1.90± 0.21</td>
<td>1.83± 0.36</td>
<td>2.01± 0.42</td>
</tr>
</tbody>
</table>
Figure 1. Postures of Surya Namaskar.

1 - First Posture
2 - Second Posture
3 - Third Posture
4 - Fourth Posture
5 - Fifth Posture
6 - Sixth Posture
7 - Seventh Posture
8 - Eighth Posture
9 - Ninth Posture
10 - Tenth Posture
11 - Eleventh Posture
12 - Twelfth Posture
Figure 2. Computerized display of oxygen consumption measurement system (Oxycon Champion, Erich Jaeger, Germany).
Figure 3. Face mask for attaching to the subject's face.
Figure 4. Opto – electronic transducer.
Figure 5. Subject seated on the bicycle Ergometer attached with face mask, Opto-electronic transducer and twin tube.
Figure 6. Electrically braked Bicycle Ergometer (ergometrics er900, ergoline, GmbH & Co KG Medical Measuring Systems, Germany).
1 – Sensor of the heart rate monitor, 2 – Chest belt
3 – Heart rate monitor  4 – twin tube

**Figure 7.** Telemetric heart rate monitor (Sports tester, Polar Electro, Finland) & Twin tube.
Figure 8. Subject wearing chest belt for monitoring heart rate.
Figure 9. Electro sphygmomanometer, Datascope U.S.A.
Figure 10. YSI (Yellow Springs Inc., U.S.A) pre calibrated oral temperature probe.