Indian J Physiol Pharmacol 2004; 48 (2) : 184–190

ENERGY COST AND CARDIORESPIRATORY CHANGES DURING THE PRACTICE OF SURYA NAMASKAR

B. SINHA, U. S. RAY*, A. PATHAK AND W. SELVAMURTHY

Defence Institute of Physiology & Allied Science,
Lucknow Road, Timarpur,
Delhi – 110 054

(Received on October 30, 2002)

Abstract : Surya Namaskar (SN), a group of Yogic exercise consists of a set of twelve postures which is practiced by some of the yoga practitioners. The present study was undertaken to observe critically the energy cost and different cardiorespiratory changes during the practice of SN. Twenty-one male volunteers from the Indian Army practiced selected Yogic exercises for six days in a week for three months duration. The Yogic practice schedule consisted of Hatha Yogic Asanas (28 min), Pranayama (10.5 min) and Meditation (5 min). In the Yogic practice schedule 1st they practiced Kapal Bhathi (breathing maneuvers) for 2 min then Yogamudra (yogic postural exercise) for 2 min, after that they took rest until oxygen consumption and heart rate (HR) came to resting value. Subsequently subjects performed SN for 3 min 40 seconds on an average. After three months of training at the beginning of the fourth month subjects performed entire Yogic practice schedule in the laboratory as they practiced during their training session and experiments were carried out. Their pulmonary ventilation, carbondioxide output, Oxygen consumption, HR and other cardiorespiratory parameters were measured during the actual practice of SN. Oxygen consumption was highest in the eighth posture (1.22 ± 0.073 1 min^{-1}) and lowest in the first posture (0.35 ± 0.02 1 min^{-1}). Total energy cost throughout the practice of SN was 13.91 kcal and at an average of 3.79 kcal/min. During its practice highest HR was 101 ± 13.5 b.p.m. As an aerobic exercise SN seemed to be ideal as it involves both static stretching and slow dynamic component of exercise with optimal stress on the cardiorespiratory system.

Key words : Surya Namaskar, Hatha Yoga, energy cost, cardiorespiratory changes

INTRODUCTION

The literal meaning of Surya Namaskar (SN) (a group of Yogic Asanas) is salutation to the Sun. This sequence of Asanas was developed in the much later period as compared to the other Hatha Yogic Asanas. It is an effective way of stretching many

*Corresponding Author : Phone No. : 23991769; Fax : 9-11-3932869

muscles and performing movement at many joints of the body. Its beneficial effects like correction of common spinal disorders, improvement in cardiac, respiratory, digestive, excretory, endocrine and mental functions are also being claimed (1, 2, 4). It consists of a cycle of twelve postures performed rhythmically with controlled breathing (3). There are reports regarding oxygen consumption and energy cost of a few Hatha Yogic asanas (5, 6), but there is no report available on oxygen consumption and cardiorespiratory aspects of SN. So the present study was undertaken to observe energy cost and various cardiorespiratory changes during the practice of SN.

METHODS

Twenty-one normal healthy male volunteers who were free from any clinical disorders and who had no prior experience of practicing Yoga were selected for the present study. Their age, height and body weight were (mean ± SEM) 21.7 ± 1.4 yrs, 172.5 ± 4.6 cms and 62.3 ± 4.3 kg respectively. Subjects being from the army had uniform pattern of daily routine activity schedule and used to have the diet supplying 3700 kcal (approximately). They gave their informed consent to participate in the study and the ethical committee of the Institute approved the study protocol.

Subjects underwent training in a battery of selected Yogic exercises daily in the morning with an empty stomach for six days in a week for three months duration under the supervision of a qualified yoga instructor. The entire Yogic exercise schedule consisted of Hatha Yogic Asanas (28 min), Pranayama (10.5 min) and Meditation (5 min). In the Yogic practice schedule 1st they practiced Kapal bhathi for 2 min then Yogamudra for 2 min after that they took rest until oxygen consumption and HR came to resting value. Then subjects performed SN (Fig. 1) for 3 min 40 seconds on an average. The time required for performing components/posture 1 to 12 of SN were 10 sec, 20 sec, 30 sec, 30 sec, 30 sec, 5 sec, 25 sec, 30 sec, 3 sec, 7 sec, 20 sec and 10 sec respectively. In the present paper only data regarding SN is being reported. The result of the some other yogic practice, reported elsewhere (7) and some are unpublished. After three months of training at the fourth month experiments were carried out in the morning. On the day of the experiment subjects performed the entire Yogic exercise schedule in the laboratory. After every individual Yogic practice subjects took sufficient rest before proceeding towards the next Yogic practice till their parameters returned to the baseline level as recorded before starting the particular yogic schedule. Physiological parameters monitored continuously during the performance of SN. Subjects were familiarized with the experimental procedures and the laboratory environment prior to the day of the experiment. Recordings were also done on the Savasana posture (lying in the supine position) for five minutes each time just before and after the performance of SN. Temperature of the laboratory was maintained between 24–28°C.

Experiments were conducted by using oxygen consumption measurement system (Oxycon Champion, Erich Jaeger, Germany). The parameters recorded were $\dot{V}_{O2}$ (oxygen consumption), $\dot{V}_{CO2}$ (carbon dioxide output).

$\dot{V}_E$ (pulmonary ventilation), V_T (tidal volume) and f_R (respiratory rate). The recordings were saved in the computer hard disk. HR was recorded by Mx lead (M stands for manubrium and x stands for xiphoid process) by ECG monitor (Model SMS-181, Hellige, Servomed, Germany).

The ventilatory equivalent for oxygen ($\dot{V}_E/\dot{V}_{O_2}$), ventilatory equivalent for carbondioxide ($\dot{V}_E/\dot{V}_{CO_2}$), respiratory exchange ratio (RER) and oxygen pulse (O_{2P}) i.e. $\dot{V}_{O2}$ divided by HR, were calculated from the basic parameters by the computer.

The data was analysed by using two way ANOVA (analysis of variance-without replication) and linear correlation was found out to observe the relationship amongst different parameters.

RESULTS

Values of $\dot{V}_{O_2}$, energy expenditure and percentage allocation of energy in individual postures with respect to total energy expenditure in SN and Savasana are given in the Table I. Values of HR, O_2P, $\dot{V}_{CO_2}$ $\dot{V}_E$, f_R, V_T, $\dot{V}_E/\dot{V}_{O_2}$, $\dot{V}_E/\dot{V}_{CO_2}$, RER during SN and during Savasana are shown in Table II. $\dot{V}_{O_2}$ was highest in the 8th posture (1.22 ± 0.073 1 min^{-1}) and lowest in the 1st posture (0.350 ± 0.02 1 min^{-1}). There is a significant correlation ($P<0.001$) between the time taken for a component of SN and the rate of energy expenditure during the component. Considering all postures, average $\dot{V}_{O_2}$ in SN was 0.771 1 min^{-1} (corresponding to 3.79 kcal min^{-1}) and total $\dot{V}_{O_2}$ throughout the period of practice was 2.83 litre (corresponding to 13.83 kcal). In the present study 2nd, 4th, 5th & 8th postures are backward bending postures and 3rd and 11th postures are forward bending. 4th and 5th postures showed higher $\dot{V}_{O2}$ than 3rd posture ($P<0.05$). 8th posture showed higher $\dot{V}_{O_2}$ than 11th posture ($P<0.001$). The 2nd posture when compared with the 3rd posture did not show any significant difference. 4th and 5th posture when compared with 11th posture also did not show any significant difference. In most

TABLE I: Oxygen consumption, energy expenditure and percentage allocation of energy in individual postures with respect to total energy expenditure (Values are mean ± SEM).

Parameters	*1st posture*	*2nd posture*	*3rd posture*	*4th posture*	*5th posture*	*6th posture*	*7th posture*	*8th posture*	*9th posture*	*10th posture*	*11th posture*	*12th posture*	*Savasana*
Oxygen consumption (lit. min^{-1})	0.350 0.020	0.420 0.031	0.534 0.028	0.658 0.029	0.771 0.040	0.868 0.045	1.009 0.053	1.222 0.073	1.009 0.071	0.868 0.040	0.964 0.060	0.401 0.030	0.253 0.023
Energy expenditure (Kcal)	0.284 0.024	0.686 0.052	1.308 0.070	1.612 0.072	1.889 0.010	0.354 0.019	2.060 0.110	2.995 0.183	0.247 0.013	0.496 0.026	1.574 0.101	0.327 0.024	1.24 0.117
%age utilisation of energy	2.05	4.96	9.46	11.66	13.66	2.56	14.90	21.66	1.79	3.59	11.38	2.36	—

TABLE II: Different cardiorespiratory parameters in different postures of Surya Namaskar. (Values are mean ± SEM).

Parameters	*2nd posture*	*3rd posture*	*4th posture*	*5th posture*	*7th posture*	*8th posture*	*11th posture*	*Savasana*
$\dot{V}_{CO_2}$	0.341	0.459	0.535	0.583	0.739	0.916	0.828	0.261
1 min^{-1}	0.097	0.151	0.132	0.152	0.183	0.186	0.204	0.099
f_R	16.9	17.6	21.4	17.8	20.2	23.1	22.7	16.9
(breaths min^{-1})	3.1	6.2	5.3	4.9	5.2	4.6	3.6	4.1
V_T	0.757	0.853	0.839	1.095	1.149	1.142	1.076	0.595
(litre)	0.307	0.300	0.224	0.292	0.252	0.243	0.244	0.156
VE	12.41	13.72	17.60	18.84	22.57	25.78	23.96	9.54
($Lmin^{-1}$ min^{-1})	3.95	3.56	4.47	4.97	5.18	4.84	4.90	1.58
Heart rate	83.5	92.8	89.5	95.9	101.6	95.0	89.0	60.1
(Beats min^{-1})	10.5	15.6	16.0	13.6	13.5	14.7	15.3	6.7
O_2 pulse	5.24	5.88	7.62	8.19	10.16	13.22	11.11	4.26
(ml $beat^{-1}$)	2.60	1.67	2.33	2.26	3.11	4.11	3.93	0.64
RER	0.9	0.8	0.8	0.8	0.8	0.8	0.9	1.0
	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.1
EQO_2	30.62	25.56	26.30	24.54	22.45	21.46	25.44	36.50
	6.01	3.78	4.02	6.24	3.34	3.88	5.39	4.73
$EQCO_2$	35.66	33.05	32.46	30.04	29.24	28.10	29.26	35.66
	4.59	3.11	2.16	2.32	1.77	2.11	1.87	4.59

of the cases backward bending postures showed higher $\dot{V}_{O_2}$ than forward bending postures. HR was found highest in the 7th posture (101.6 ± 13.5 beats per minute) and lowest in the 2nd posture (83.5 ± 10.5 beats per minute). Oxygen pulse was highest in the 8th posture (13.22 ± 4.11 ml $beat^{-1}$) and lowest in the 2nd posture (5.24 ± 2.60).

There was no significant correlation between $\dot{V}_{O_2}$ and HR throughout the practice of SN ($r = +0.743$) ($P = 0.146$). There was no significant correlation between f_R and V_T ($r = +0.532$) ($P = 0.218$). There were correlation between $\dot{V}_E$ and $\dot{V}_{O_2}$ ($r = +0.982$) ($P<0.001$) and $\dot{V}_E$ and $\dot{V}_{CO_2}$ ($r = +0.992$) ($P<0.001$). A weaker correlation was there between V_T and HR ($r = +0.764$) ($P<0.05$).

If gradation was done on the basis of $\dot{V}_{O_2}$ and energy expenditure the different postures of SN appear in the following ascending order 2nd, 3rd, 4th, 5th, 9th and 8th posture.

$\dot{V}_E$ increased significantly from 3rd posture to 4th posture ($P<0.001$) and from 5th to 7th posture. $\dot{V}_{CO_2}$ increased significantly from 2nd posture to 3rd posture ($P<0.01$) and from 5th posture to 7th posture. O_2P increased significantly from 3rd to 4th posture ($P<0.05$), from 5th to 7th posture ($P<0.01$) and from 11th to 8th posture ($P<0.01$). $\dot{V}_E/\dot{V}_{O_2}$ significantly decreased from 2nd to 4th posture ($P<0.001$) ($P<0.001$). $\dot{V}_E/\dot{V}_{O_2}$ significantly decreased from 2nd to 3rd and from 4th to 5th posture.

3rd posture when compared with the 11th posture, showed that $\dot{V}_{O_2}$ (ml/min/kg),

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

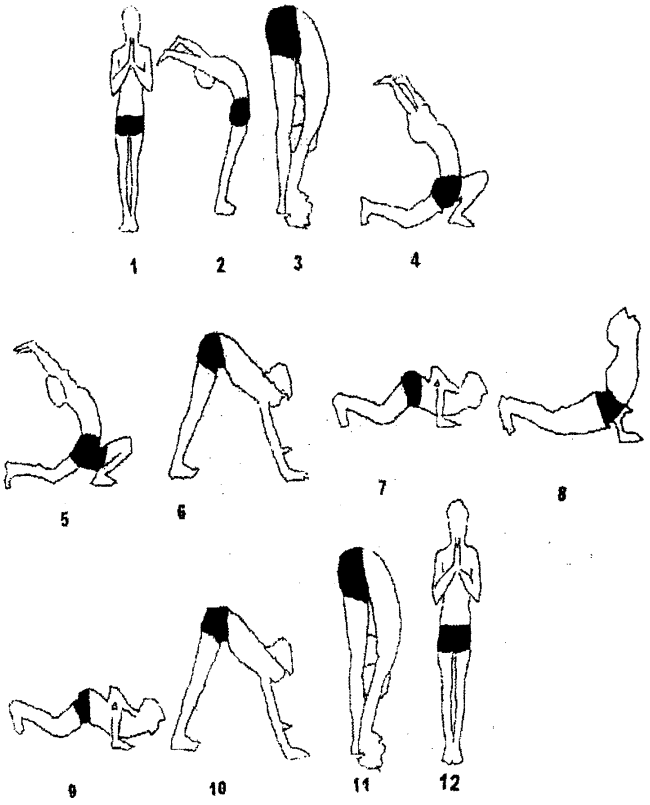

Fig. 1: Postures of Surya Namaskar.

O_2P, $\dot{V}_{CO_2}$, f_R, V_T, $\dot{V}_E$ significantly increased at 11th posture from 3rd posture ($P<0.001$). HR and $\dot{V}_E/\dot{V}_{O_2}$ did not show any significant difference between two postures. $\dot{V}_E/\dot{V}_{CO_2}$ significantly decreased from 3rd posture to 11th posture ($P<0.001$).

DISCUSSION

Surya Namaskar consists of 12 postures performed sequentially over a short period of time (3). Several of the postures occur twice in each cycle. For the measurement of energy expenditure we have considered all the 12 postures in the present study. Rests of the parameters recorded were based only on the seven postures (2nd, 3rd, 4th, 5th, 7th, 8th and 11th posture).

1st posture is characterized by low $\dot{V}_{O_2}$ (0.350 litre min^{-1}) which is slightly higher than the Savasana (0.253 litre min^{-1}). 2nd posture is characterized by $\dot{V}_{O_2}$ higher than the 1st posture since larger group of muscles are involved. During its practice vertebral column is extended/bent backwards. Group of muscles at the trunk and abdominal regions get involved to attain this. HR is also lowest amongst all other postures except the 1st posture.

3rd posture was estimated to have more $\dot{V}_{O_2}$ than preceding 1st and 2nd posture. This may be due to the carry over effect of the earlier two postures and involvement of greater muscle mass. So, $\dot{V}_{O_2}$ in it also increased as compared to the 1st posture ($P<0.001$). Likewise, the value of $\dot{V}_{O_2}$ progressively increased up to 8th posture. The value of HR increased significantly except in the 4th posture and 8th posture. HR increased significantly only from 2nd to 3rd posture ($P<0.01$). Other postures did not show any significant difference. 7th posture showed highest HR amongst all other postures probably due to involvement of large number of smaller group of muscles in the hand. It appears that the 8th posture is comparatively more strenuous amongst all other postures and is characterised by highest $\dot{V}_{O_2}$, f_R, $\dot{V}_E$, O_2P, $\dot{V}_{CO_2}$ and lowest $\dot{V}_E/\dot{V}_{CO_2}$. Maximal oxygen consumption was determined for each subject (7). The 8th posture was performed at approximately 41.1% of $\dot{V}_{O_2}$ max. Average energy expenditure during SN is closer to the value as reported by other investigators during the practice of yoga (8) (3.8 kcal min^{-1}) but the value of specific yogic exercises was not available.

Brahmachari et. al. (9) compared individual yogic postures in yoga proficient subjects and reported metabolic cost for Savasana, Siddhasana, Paschimottanasana, and Bhujangasana as 1.06, 1.23, 1.45 and 2.62 kcal min^{-1} respectively. Although posture 8 in the present study is similar to the Bhujangasana, it showed higher energy cost (6 kcal min^{-1}) than Bhujangasana (2.62 kcal min^{-1}) as reported by Brahmachari et al. This may be due to the latency of the response and carry over effect of one posture on the other. Hence it has been seen that SN was comparatively strenuous than these Asanas.

They have also reported in another study (10) that asanas involving backward bending postures show higher energy cost than the forward bending postures by comparing Dhanurasana (backward bending) with Paschimottanasana. In Dhanurasana greater muscle mass is involved than the Paschimottanasana. In this study the backward bending position (2nd position) involves lesser muscle mass as compared to Dhanurasana. So it requires a cautious approach while drawing a general conclusion that backward bending posture would have higher energy cost than the forward bending postures. In this study also some of the backward bending postures showed higher oxygen demand than the forward bending postures in Surya Namaskar. Posture 4 and 5 (back ward bending) had higher $\dot{V}_{O_2}$ values than posture 3. Again posture 8 (similar to Bhujangasana – a backward bending posture had higher oxygen consumption than posture 11 (forward bending) which should have highest carry over effect of previous postures. Here, the reason for this may be due to the involvement of larger number of muscle mass in the backward bending posture.

Some investigators (11) reported the value of energy cost during the practice of different events of gymnastics and have shown that in parallel bar, balance beam and Pommel Horse energy cost were 8.4 kcal kg^{-1} hr^{-1}, 6.6 kcal kg^{-1} hr^{-1} and 9.0 kcal kg^{-1} hr^{-1} respectively. In the present study the energy expenditure during the practice of SN was only at 3.60 kcal kg^{-1} hr^{-1} which

suggests that metabolic demand was less in SN. Maximum heart rate being within 101.6 ± 13.5 b.p.m. SN also shows comparatively lower cardiovascular stress.

Apparently while considering $\dot{V}_{O_2}$, $\dot{V}_{CO_2}$, $\dot{V}_E$, RER, $\dot{V}_E/\dot{V}_{O_2}$ and $\dot{V}_E/\dot{V}_{CO_2}$ of different postures it seems that throughout its practice a practitioner remains within his anaerobic threshold/lactate threshold (even in higher $\dot{V}_{O_2}$ at 8th posture i.e. 41.1% of $\dot{V}_{O_2}$ max).

Characteristically SN, a special set of yogic asanas having both static stretching and dynamic muscular exercise components involving majority of joints, muscles and possibly different internal organ systems of the body, is an all round Yogic practice. Since, it keeps one within his lactate or anaerobic threshold and exerts a moderate stress on cardiorespiratory system, it is an ideal form of aerobic exercise.

ACKNOWLEDGEMENTS

Help rendered by Dr. P. K. Banerjee Sc. 'F', Director DIPAS is gratefully acknowledged. We express our sincere thanks to Ms. Tulika Dasgupta, JRF for helping in compilation of the data. Thanks are due to Sh. Laxmi Narayan Bhagat, Yoga Instructor who has helped to train the subjects in Yogic practices. Last but not the least we are very thankful to the experimental subjects for their active cooperation in the study.

REFERENCES

1. Yogeswar. Text book of Yoga, 1st Edn:, Madras, Yoga Centre, Mylapore, 1980; 38–52.
2. Saraswati SS Surya Namaskar, salutation to the sun. In: Asanas Pranayama Mudra Bandha. Editors: Bihar Yoga Bharati, Munger, Bihar, India 1997; 159–172.
3. Pratinidhi BP. Surya Namaskars. In: An ancient Indian exercise, IIIrd Edn., Mumbai, Orient Longman Limited, 1989; 1–6.
4. Sivanda Swami. Surya Namaskar. In: Science of Yoga, (Eds) Swami Krishnanda, Vol. 4, Pondichery, India, All India Press, 1981; 37–39.
5. Rai L, Ram K, Kant U, Madan SK, Sharma SK. Energy expenditure and ventilatory responses during siddhasana – a yogic seated posture. *Indian J Physiol Pharmacol* 1994; 38(1): 29–33.
6. Rai L, Ram K. Energy expenditure and ventilatory responses during virasana – A yogic standing posture. *Indian J Physiol Pharmacol* 1993; 37(1): 45–50.
7. Ray US, Mukhopadhyay S, Tomer OS, Sinha B, Pathak A, Thakur L, Anand JP and Selvamurthy W. Physiological responses during the practice of individual yogic exercises (asanas) yogic breathing (pranayama) and meditation in yoga tranees and proficient. *Delhi, DRDO, Ministry of Defence Report No. RD-P1-96/DIP-212* (USR), 2000.
8. Mc Ardle WD, Katch FI, Katch VL. Exercise Physiology. USA 4th Ed. William and Willkins, 1996; 769–781.
9. Brahmachari D, Vachani V, Sahani S, Ram K and Rai L. A comparative study of some individual yogic postures on ventilatory responses in yoga proficient subjects. *J Res Edu Ind Med* 1989; 3: 7–17.
10. Brahmachari D, Vachani S, Sahani S, Ram K, Rai L. Cardioventilatory responses to yogic practices of Muktasana, Paschimottanasana and Dhanurasana. *J Res Edu In Med* 1989; 3: 19–29.
11. Drinkwater BL. Physiological responses of women to exercise. In: Exercise and Sport Science reviews. Editors Jack H. Wilmore, Vol. I, New York and London, Academic Press, 1973; 126–153.