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Physiological responses to cold (10° C) in men after six months' practice of yoga exercises

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Abstract. A study was conducted on 30 healthy soldiers (age: 40–46 years) to assess the effect of selected yogic exercises (asanas) on some physiological responses to cold exposure. They were randomly divided into two groups of 15 each. One group performed regular physical exercises of physical training (PT), while the other group practised yogic exercises. At the end of 6 months of training, both the groups were exposed together to cold stress at 10° C for 2 h, and the following parameters were periodically monitored during cold exposure: heart rate (*fH*), blood pressure (*BP*), cardiac output ($\dot{Q}_c$), oral temperature (T_{or}), skin temperature (T_{sk}), respiratory rate (*fR*), minute ventilation ($\dot{V}_E$), oxygen consumption ($\dot{V}_{O_2}$), and shivering response by integrated electromyogram (EMG). There were progressive increases in *BP*, *fR*, $\dot{V}_E$, $\dot{V}_{O_2}$, and $\dot{Q}_c$, and decreases in *fH*, T_{or} and T_{sk} during cold exposure in both the groups. However, the decrease in T_{or} and the increases in $\dot{V}_{O_2}$ and $\dot{V}_E$ were relatively lower ($P < 0.01$) in the yoga group as compared to the PT group. The shivering response appeared much earlier and was more intense in the PT group. These findings suggest that practice of yoga exercises may improve cold tolerance.

Key words: Yoga exercises – Physiological responses – Men – Cold

Introduction

Yoga, an ancient Indian cult and way of life, is reported to improve physiological and psychological functions of its practitioners (Anand et al. 1961; Mayol 1966; Udupa et al. 1975; Nayar et al. 1975; Stanescu et al. 1981; Selvamurthy 1983). These beneficial responses appear to be brought about by the modulation of autonomic nervous system activity and by improving cardiorespiratory and endocrine functions. Our previous studies indicate that 6 months of yogic practice can result in stability of autonomic balance, improvement in body flexibility, muscular efficiency, biochemical profile, and physical and mental performance in young and middle aged soldiers (Santha et al. 1981; Selvamurthy 1983; Ray et al. 1983; Selvamurthy et al. 1983; Ray et al. 1986). Some of these studies also indicate a trend of possible improvement in tolerance to stress.

Yogis are reported to possess a better cold tolerance (Bhatnagar et al. 1978) and they can even voluntarily raise their skin temperature by 8.3° C on cold exposure (Benson et al. 1982). It is not known whether even short-term practice of yogic exercises, say for 6 months, can improve cold tolerance in a common man who does not follow the rigours of yogic life. Thus, the present study was conducted on young healthy soldiers to evaluate the effect of 6 months practice of yogic exercises (asanas and pranayama) on physiological responses to cold exposure, and to compare these responses with those of another group doing conventional physical exercises for the same duration.

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Materials and methods

Thirty healthy men (soldiers) served as subjects for the study. They were randomly divided into two groups of 15 each. There were no statistically significant differences in mean age, height and weight between the two groups of subjects. Their physical characteristics are given in Table 1. One group was assigned to routine physical training (PT group), whereas the other group (yoga group) practised selected Hatha yogic exercises. Both the groups had exercise training from March till August in the open field between 7–8 a.m. at an ambient temperature of between 20–28° C and a relative humidity, of between 50%–85% under the supervision of two qualified instructors for a period of 6 months. The yogic schedule consisted of prayer

Table 1. Physical characteristics of subjects[a]

Group	Age (years)	Height (cm)	Body weight (kg)	
			Before training	After training
Yoga	41.7±1.69	170.1±4.53	67.2±8.14	65.7[b]±6.2
Physical exercise	41.2±1.17	170.6±4.81	62.2±6.79	61.2 ±7.8

[a] Values are mean±standard deviation
[b] $P<0.01$

Table 2. List of yogic exercises (asanas)

Padmasana	Sarvangasana
Yoga mudra	Halasana
Matsyasana	Karna Peedasana
Pavanamukhtasana	Bhujangasana
Dhanurasana	Parvathasana
Surya namaskar	Nauli
Paschimotanasana	Chakrasana
Shavasana	

(for 2 min) followed by Hatha yogic asanas (50 min) as listed in Table 2, pranayama or breathing exercises (5 min) and meditation (5 min). The physical exercise programme, on the other hand, consisted of running for 4 km (30 min), body flexibility exercises (10 min), pull-ups (5 min) and games (15 min). It is known that conventional physical training can be at a submaximal level, while yogic exercises are reported to be much below the submaximal level of exercise (Nayar et al. 1975). Salgar et al. 1975 also reported a definite increase in oxygen consumption up to 100 ml/min during one type of asana (padmasana). The energy cost has not been measured during physical training or yogic schedule in the present experiment. However, in our protocol the total duration was kept identical for both groups. Fifteen yogic asanas (Table 2) were selected for the study as these asanas have been observed by us to influence autonomic functions (Selvamurthy 1983), physical efficiency (Selvamurthy et al. 1983), body flexibility (Ray et al. 1983), biochemical profile (Santha et al. 1981) and muscular efficiency (Ray et al. 1986). The details regarding the methods of practice of asanas are described elsewhere (Yogeswar 1980). All the 15 asanas were practised daily by all the subjects of the yoga group. The sequence of practice of the asanas was as given in Table 2. The posture of each asana was maintained for about 2 min. The Shavasana was intermittently practised for about 2 min after completing 4 asanas in this sequence. Subjects were instructed to perform these asanas in a relaxed state and being fully conscious of the physical movements. The final posture of the asanas are shown in Fig. 3. As seen in the figure, there are flexing (forward bending: see 2nd, 3rd, 6th, 7th, 8th, 13th postures in Fig. 3) and extension (backward bending: 1st, 4th, 5th, 9th, 10th, 11th, and 12th postures in Fig. 3) exercises along with postural changes. The flexing group of exercises are usually accompanied by slow exhalation after deep inhalation during forward bending, while backward bending exercises are accompanied by inhalation during dynamic phases of the exercise. Soon after the final pose is reached, the subjects breathe normally. These exercises are done with smooth movement, without undue jerks, and the emphasis is laid on relaxation between groups of asanas by practising Shavasana, as in posture number 14 in Fig. 3.

The subjects, being soldiers, had a uniform pattern of routine daily activities and a balanced diet supplying approx. 15,480 KJ. Their informed consent was obtained before the commencement of the study. At the end of 6 months' training, physiological responses to cold exposure were studied by exposing both groups of subjects together in a cold chamber for 2 h. The climatic chamber was maintained at $10° \pm 1°$ C with an air flow at 6 m/min. Two subjects (one from PT and one from the yoga group) were tested at a time. The recording of the physiological variables was carried out while they were sitting on a bench supplied with a back rest; subjects were in the sitting posture throughout exposure to the physiological recording. Heart rate (*fH*) was recorded by auscultation by counting the rate for 2 min, while *BP* was measured on a sphygmomanometer. Thermistor probes were placed mid-thigh for recording skin temperature (T_{sk}) and in the mouth for 3 min to record oral temperature on a YSI telethermometer (46 TUC). These were recorded prior to and at 30 min intervals during exposure. Shivering response was assessed by integrated electromyogram (EMG) from thigh muscles and was graded as mild (+), moderate (+ +) or intense (+ + +). Cardiac output ($\dot{Q}_c$) was recorded before and after 2 h exposure by impedance plethysmograph. Oxygen consumption ($\dot{V}_{O_2}$) and minute ventilation ($\dot{V}_E$) were recorded at the beginning, and after 1 h and 2 h of exposure. Physical efficiency for all subjects was measured initially and at the end of 6 months of yoga/physical exercise training. Physiological responses to standard submaximal exercise were measured by making the subjects step on and off a 40 cm high wooden stool at a rate of 25 steps per minute for 6 min. Heart rate and ventilation were recorded in the resting condition and during the last minute of exercise, and expired air samples were also collected and analysed. For measuring lactic acid content, blood samples were collected at rest and at the end of exercise. EMG was recorded using surface disc electrodes on a Beckman R type Dynograph with an EMG integrator coupler. Cardiac output was recorded by Bionics Digital Impedance Plethysmograph. For oxygen consumption, expired air samples were collected by Kofranyi-Michaelis meter and analysed by Scholander micro gas analyser. Ventilation was also determined using the Kofranyi-Michaelis meter.

Results

There was a progressive fall in T_{or} and T_{sk} during exposure to cold in both groups (Fig. 1). However, the magnitude of fall in T_{or} was relatively less ($P<0.01$) in the yoga group as compared to the PT group. Both groups showed a significant ($P<0.001$) decrease in *fH* during cold exposure (Fig. 2). The PT group reached the lowest value within 30 min of exposure, while the yoga group maintained a higher ($P<0.05$) *fH* up to 45 min. $\dot{V}_E$ and $\dot{V}_{O_2}$ markedly increased during 2 h of cold exposure (Fig. 2), but the yoga group showed a relatively lower increase ($P<0.05$) in $\dot{V}_{O_2}$ during the first hour of exposure. Blood pressure showed a significant increase in both groups during the cold exposure (Table 3) and this response was not significantly different between the groups. Shivering appeared much earlier and was more intense in the

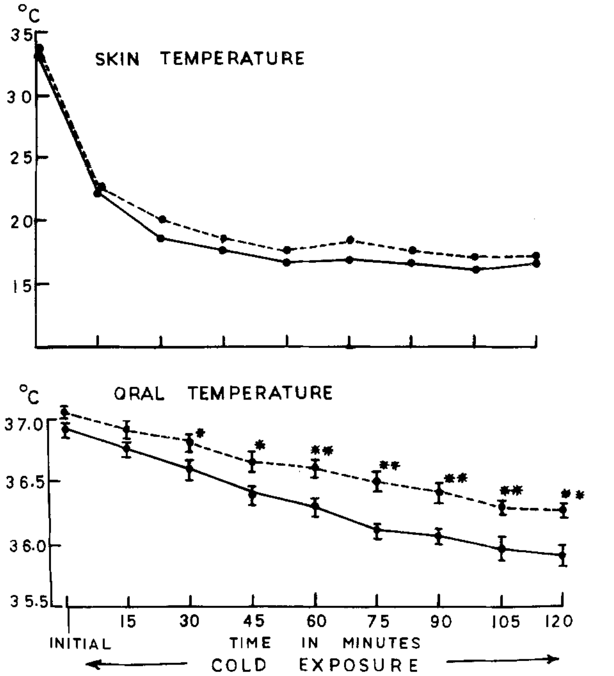

Fig. 1. Changes in skin and oral temperatures during 120 min of cold exposure in the PT and yoga groups at the end of 6 months of the course. ●—● PT group; ●---● yoga group; * $P<0.05$; ** $P<0.01$. Values are mean ±SEM

PT group. Cardiac output and stroke volume showed a slight increase after 2 h exposure (Table 4), but the magnitude of increase was almost the same in both groups. With submaximal exercise, the yoga group showed a significant reduction in exercise heart rate ($P<0.01$), oxygen consumption ($P<0.05$) and blood lactic acid content ($P<0.001$) at the end of training as compared to the values before training, while in the PT group, only exercise lactic acid showed a marginal decline ($P<0.05$). Body weight showed a significant ($P<0.01$) reduction in the yoga group after 6 months of training, while the PT group showed only a non-significant decrease (Table 1).

Discussion

The data obtained in the present study show a definite positive trend of improvement in cold tolerance in the yoga group as compared to the PT group. The yoga group could maintain a relatively higher body temperature throughout the period of cold exposure in spite of a similar degree of cutaneous vasoconstriction, as observed from the similar T_{sk} response (Fig. 1). Thus, it is logical to infer

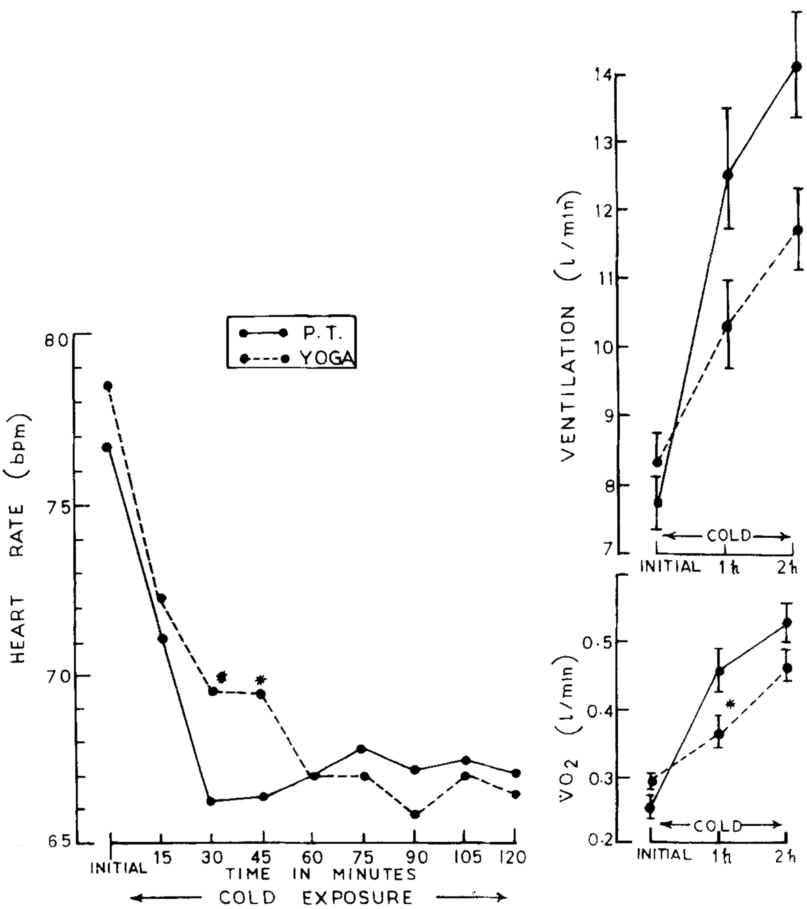

Fig. 2. Heart rate, ventilation and oxygen consumption ($\dot{V}_{O_2}$) during cold exposure in both groups. ●—● PT group; ●---● yoga group; * $P<0.05$. Values are mean ±SEM

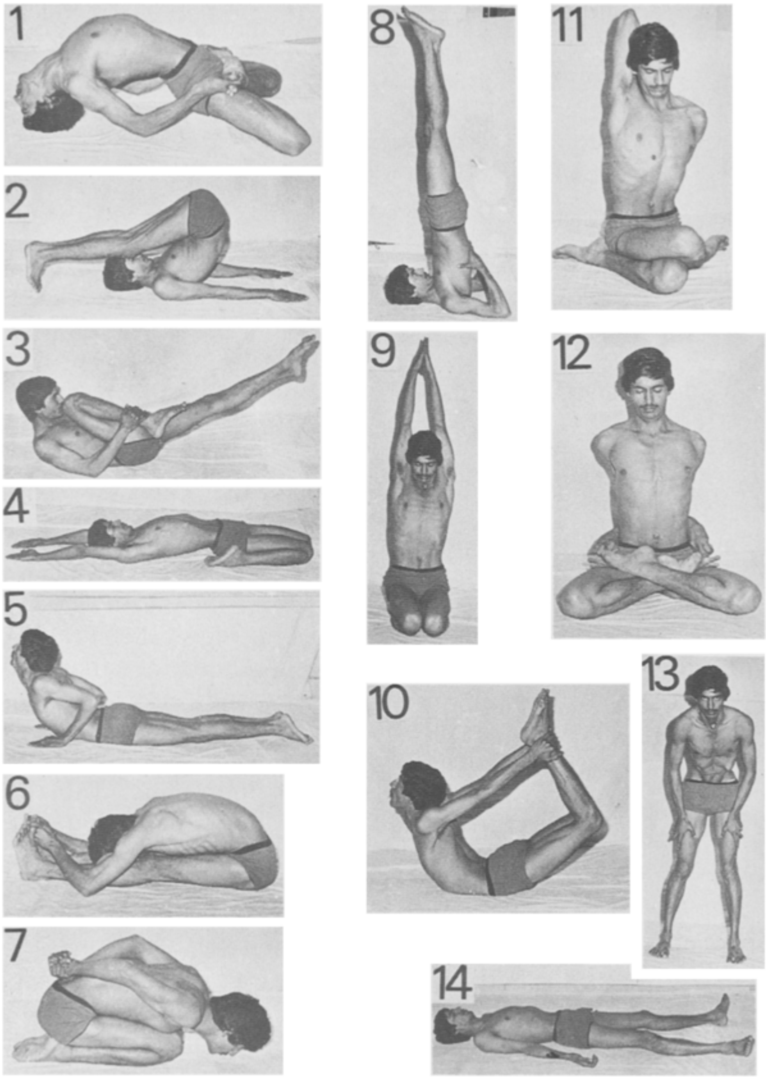

Fig. 3. 1–14 The final postures of yogasanas are shown. The names of the asanas are as follows: **1** Matsyasana, **2** Halasana, **3** Pavanmukhtasana, **4** Supta Vajrasana, **5** Bhujangasana, **6** Paschimotanasana, **7** Yoga mudra, **8** Sarvangasana, **9** Parvatasana, **10** Dhanurasana, **11** Gomukhasana, **12** Baddha Padmasana, **13** Nauli, **14** Shavasana

Table 3. Blood pressure (BP) and shivering response to cold exposure at 10° C[a]

Parameter	Initial	Duration of cold exposure (min)			
		30	60	90	120
BP (systolic; mm Hg)					
PT	108±4.2	133±3.3	140±4.7	140±4.3	139±3.9
Yoga	111±2.7	132±3.1	138±4.2	139±4.3	140±4.6
BP (diastolic; mm Hg)					
PT	73±2.9	88±2.9	93±2.7	92±2.0	96±2.7
Yoga	74±2.2	89±2.7	93±2.8	94±3.0	94±2.5
Shivering					
PT	–	–	+ +	+ + +	+ + +
Yoga	–	–	–	+	+ +

[a] Values are mean±SEM

PT, Physical training;

+ mild, + + moderate, + + + intense

Table 4. Changes in cardiac output and stroke volume before and after cold exposure[a]

Parameter	PT group		Yoga group	
	Before	After	Before	After
Cardiac output ($l\ min^{-1}$)	4.99 ±0.127	5.15 ±0.270	5.19 ±0.265	5.52 ±0.185
Stroke volume (ml)	66.7 ±1.60	77.2 ±3.94	68.6 ±2.96	83.7 ±2.35

[a] Values are mean±SEM

that the maintenance of a higher core temperature might have been brought about by an improvement in thermogenesis rather than by minimising heat dissipation.

Thermogenesis can be achieved by a shivering or nonshivering (metabolic) response (Itoh 1974;

Table 5. Physiological responses to submaximal exercise before and after 6 months of PT or yoga

Parameter	PT group		Yoga group	
	Before	After	Before	After
Heart rate (bpm)	164 ±3.9	158 ±3.2	166 ±5.4	154 ±3.9[b]
Ventilation ($1\ min^{-1}$ BTPS)	52.2 ±1.67	54.3 ±1.68	53.8 ±2.17	52.1 ±2.12
Oxygen consumption ($1\ min^{-1}$ STPD)	1.84±0.04	1.86±0.05	1.94±0.06	1.83±0.06[a]
Lactic acid (mg %)	64.1 ±2.15	59.0 ±2.40[a]	59.4 ±3.23	46.0 ±2.08[c]
Oxygen pulse	11.3 ±0.40	11.9 ±0.45	11.8 ±0.48	12.0 ±0.44
Ventilation equivalent	28.5 ±0.78	29.4 ±0.79	27.7 ±0.74	28.4 ±0.77

Values are mean ± SEM

[a] $P<0.05$; [b] $P<0.01$; [c] $P<0.001$

BTPS, Body Temperature, pressure saturated with water vapour
STPD, Standard Temperature (°C), pressure (760 mmHg) Dry

Leblanc 1975). Shivering, however, appeared much later and was less intense in the yoga group (Table 3). Thus, it appears that the nonshivering response appreciably contributed to thermogenesis in the yoga group. Norepinephrine, thyroxine and other metabolically active hormones are reported to play an important role in nonshivering thermogenesis (Wallace et al. 1971; Yoshimura 1978). This method of heat production may be more economical than the shivering thermogenesis. This is further supported by the lower increase in $\dot{V}_{O_2}$ and $\dot{V}_E$ observed in the yoga group (Fig. 2).

Physical conditioning due to exercise has been shown to improve cold tolerance in man (Sholander 1958; Keatinge 1960; Kollias et al. 1972). As the energy expenditure during yoga training is much below the submaximal level of work (Salgar et al. 1975), physical conditioning achieved by yoga exercises may be of a different kind, which needs to be investigated. In our subjects, the yogic exercise group showed an improvement in physical efficiency by a significant reduction in exercise heart rate, oxygen consumption and blood lactic acid level at a submaximal level of exercise after 6 months of training (Table 5). However, no such change was observed in the PT group except for a marginal decline in blood lactic acid level. The intensity of the two training regimes has not been quantified in the present study as these exercises fall into two different categories: in yoga relaxation is emphasized, while in PT the emphasis is on endurance and muscle power. Salgar et al. (1975) reported an increase in oxygen consumption of up to 100 ml during the practice of Padmasana. A similar increase in oxygen consumption, of 10% of maximal oxygen uptake capacity, may also be expected in other asanas. The PT exercises, on the other hand, are more intense and are likely to be of about 50%–60% of maximal oxygen uptake capacity. Our previous studies also showed a significant improvement in physical efficiency due to 6 months of yogic training (Selvamurthy 1983; Ray et al. 1986). As well as the physical conditioning, the metabolic and neuroendocrine effects of yogic exercises might play a significant role in improving cold tolerance in yoga practitioners.

The decrease in body weight observed in the yoga group after 6 months of training (Table 1) suggests a reduction in body fat, which could otherwise have given insulation against heat loss on exposure to cold. However, estimation of body fat has not been done in the present study. The difference in body weight between the yoga and PT groups both before and after training is not statistically significant. Benson et al. (1982) noticed an extraordinary capacity to voluntarily raise the skin temperature by 8.3° C in a special sect of Tibetan g-tum-mo yoga practitioners who have been practising the pranayama type of breath control exercises for several hours a day regularly for many years. It is a common observation that several yogis visit or live in caves of cold Himalayan ranges with minimum clothing in order to do 'Sadhana' or 'Thapasya' (meditation). Perhaps several years of rigorous yogic practice may be required to achieve such a high level of metabolic adaptation. In the present study, even 6 months of practice of yogic exercises has shown a definite trend of improvement in cold tolerance.

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