

A comparative study of the effects of asan, pranayama and asan-pranayama training on neurological and neuromuscular functions of Pondicherry police trainees

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ABSTRACT

Background: Though neurological benefits of yoga training have been reported, lacunae still exists in understanding neurophysiological effects of such training. Hence, the present study was conducted to find the effect of yogasanas and pranayams on neurological and neuromuscular functions in healthy human volunteers and also determined differential effects of training in asan, pranayama and their combination.

Materials and Methods: Eighty male trainees from Pondicherry Police Training School were randomly divided into asan, pranayama, and asan-pranayama groups who received a training of 4 days a week for 6 months and a control group. Electroencephalogram (EEG), nerve conduction (NC), electromyogram (EMG), visual evoked potentials (VEP), and auditory reaction time (ART) were recorded before and after the study period. NC, EMG, and VEP data were obtained from 28 subjects; EEG data from 48 subjects; and RT from 67 subjects. Intergroup differences were assessed by AVOVA/Kruskal-Wallis and intragroup differences by Student's *t*-test.

Results and Discussion: Police trainees showed beneficial effects of yoga training, although they were undergoing intensive police training and the yoga training was relatively less intense. Alpha, theta, and total power of EEG increased as a result of asan training. A shortening of visual reaction time and a decrease in red-green discriminatory reaction time signifies an improved and faster processing of visual input. They also showed a decrease in resting EMG voltage, signifying better muscular relaxation following pranayama training. Beta, theta and total power of EEG increased. ART and red-green discriminatory reaction times decreased in the trainees, signifying a more alert state as well as improved central neural processing. A combination of asan and pranayama training for 6 months produced an improvement in motor and sensory nerve conduction. Total power of EEG, alpha and theta power as well as delta % increased, while reaction time decreased signifying an alert and yet relaxed state of the neuromuscular system.

Summary and Conclusion: The present study has shown that 6 months training in asan, pranayama as well as their combination is effective in improving physiological functions of police trainees. They showed beneficial effects of yoga training, although they were undergoing intensive police training and the yoga training was relatively less intense. Hence, we recommend that yoga training be introduced in police training curricula.

Key words: Asan-pranayama; neurophysiology; police trainees; yoga training.

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INTRODUCTION

Yoga is the ancient heritage of India that has given man the answers to his spiritual and holistic search for perfect health and well-being. It is an effective and time-tested method for improving overall health and managing psychosomatic and chronic degenerative disorders. Recently, there has been an increased awareness and interest in health and

natural remedies amongst the general public as well as health professionals.

Numerous scientific studies from Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER) and other laboratories all over the world have shown that yoga has beneficial effect on our physiological and psychological functions.^[1-5] There is evidence that pranayama training produces deep psychosomatic relaxation and improvement of cardiorespiratory efficiency.^[6,7] This improvement could be either peripheral (heart and lung physiology) or central (brain regulation of these functions by autonomic nervous system). Raghuraj *et al.*^[8] have found that practice of nadishuddhi pranayama results in alteration of autonomic balance towards the parasympathetic side whereas bellows type pranayama like kapalabhati increases the sympathetic activity. Ramamurthi^[9] has suggested that yoga training might help to achieve voluntary control over medullary autonomic centers to achieve supernormal functions. The neurological benefits of yoga have interested scientists all over the world and studies have reported beneficial effects in both peripheral nerve function as well as central neuronal processing.^[10-14]

Modern life is full of stress and stress-related disorders are rampant in today's world. The very existence of mankind is threatened by new epidemics of stress-related disorders that disrupt human life. Yoga is the panacea for modern stress epidemics and has been demonstrated to be an answer to stress and stress-related disorders.^[15] The yogic lifestyle, yogic diet, yogic attitudes, and various yogic practices help man to strengthen his body, mind, and develop positive health. Yoga enables us to withstand stress by normalizing the perception of stress, optimizing the reaction to it, and by effectively releasing the pent-up stress through various yogic techniques. Yoga has various facets and the main techniques that are useful for modern man are hatha yogasanas, pranayamas and meditation. These are most effective when performed consciously and with awareness.

Yogasanas help to develop strength, flexibility, willpower, good health, and stability; and when practiced as a whole with the other limbs of yoga, they give the practitioner a 'stable and unified strong personality'. Yoga pranayamas help us to control our breath and through this breath control to attain the mental poise or *samatvam* (Bhagavad Gita). Regulated slow, deep, and rhythmic breathing is ideal for controlling stress and in overcoming emotional hang-ups. However, to the best of our knowledge, there is no systematic study quantifying modulation of stress and related neurophysiological functions with the practice of yoga for 6 months. Also, there are still many lacunae in our understanding of the neurophysiological basis of yogic techniques and the mechanisms of their action. To shed more light on these phenomena as well as to put yoga on a firm scientific pedestal and popularize it among the general

public, we planned to undertake a systematic study on the effect of different yogic techniques on neurophysiological functions.

The aims and objectives of the present study were:

1. To study the effect of yogasanas and pranayamas on neurological and neuromuscular, functions in healthy human volunteers.
2. To determine the differential effects of training in asan, pranayama and their combination.

MATERIALS AND METHODS

Subjects

Eighty male trainees aged 24.82 ± 3.20 (SD) of Pondicherry Police in the Police Training School, Indra Nagar, Pondicherry were recruited for the present study. Their height, weight, and BMI were 1.72 ± 1.16 m, 67.18 ± 6.17 kg, and 23.06 ± 1.97 units, respectively. The institutional ethics committee approved the study protocol. All the subjects gave informed consent. Exclusion Criteria: (i) Previous experience of yoga training. (ii) History of major medical illness in the past, for example, tuberculosis, hypertension, diabetes mellitus, bronchial asthma, etc. (iii) History of major surgery in the recent past. (iv) Color blindness.

Training

Subjects were randomly divided into the following groups: Group I (asan group): The subjects were taught the following yogasanas for two weeks under the guidance of a qualified yoga teacher: Talasana, utkatasana, trikonasana, ardha-matsyendrasana, bakasana, pavanamuktasana, navasana, noukasana, matsyasana, pashchimottanasana, halasana, bhujangasana, shalabhasana, sarvangasana and shavasana.^[16,17]

Group II (pranayama group): The subjects were trained to perform the following pranayamas: Vibhag pranayama, mukh bhastrika, mahat-yoga pranayama, nadi shuddhi and savitri pranayama. After 2 weeks of training, they practised the same under supervision for an hour daily 4 days a week, for a total duration of 6 months.^[16,17]

Group III (asan-pranayama group): The subjects were taught a combination of all the practices that were taught to group I and group II.

Group IV (control group): The subjects of this group did not receive any yoga training. They were asked to continue their regular activities throughout the period of the study.

Parameters

Two or three days before actual recordings, the subjects

were familiarized with the laboratory environment and their anthropometric measurements were taken. On the day of the test, subjects reported at the laboratory 2 h after a light breakfast. The laboratory temperature was maintained at $27 \pm 1^\circ\text{C}$. Subjects refrained from smoking, alcohol, and caffeinated drinks on the morning of the test. None of them were taking any medication at the time of the testing.

1. Electroencephalogram (EEG)
2. Electrophysiological parameters:
 - i. Nerve conduction (NC)
 - ii. Electromyography (EMG)
 - iii. Visual evoked potentials (VEP)
3. Simple and choice reaction time (RT):
 - i. Auditory reaction time (ART)
 - ii. Visual reaction time (VRT).

Due to the time consuming nature of the neurophysiological testing, tight schedule of the labs that also cater to hospital patients, and the inability of the subjects to come more than twice, the actual number of subjects varied in the different parameters. NC, EMG, and VEP data were obtained from 28 subjects; EEG data from 48 subjects; and RT parameters from 67 subjects. These parameters were recorded in all the four groups at the beginning of the study and again at the end of 6 month study period.

Electroencephalogram

Surface electrodes were fixed using an electrode cap on the scalp of the subject according to 10-20 international electrode placement system. EEG recording was acquired continuously for 10 min (5 min eyes open followed by 5 min eyes closed) using BIOPAC MP 100 hardware (BIOPAC Inc., USA). The spectral analysis of EEG of the right occipital area was performed using a Fast Fourier Transform (FFT) algorithm of the artifact-free epoch and the power spectra of alpha, beta, theta and delta waves were analyzed using the BIOPAC AcqKnowledge 3.7.1 software (BIOPAC Inc., USA) and a Microsoft Windows-based PC. Spectral power was obtained by integrating the power spectrum from 8-15 Hz (alpha), 14-30 Hz (beta), 4-7 Hz (theta) and 1-3.5 Hz (delta) and the percentage of the respective wave in relation to the total power was calculated.

Electrophysiologic studies

All electrophysiologic studies were done using EP-EMG Medelec Sapphire system (Sapphire II, Medelec, UK). The methods followed were those recommended by Aminoff.^[18]

Median nerve motor conduction: The method adopted was that of Johnson.^[19] Active recording electrode was placed on thenar eminence of the dominant hand at the midpoint between metacarpophalangeal joint of thumb and midpoint of distal crease. Reference electrode was placed distally on thumb and ground electrode was

wrapped around the wrist. Distal latency was recorded by stimulating median nerve, 8 cm proximal to the active electrode located between the palmaris longus and flexor carpi radialis tendon. Proximal latency was recorded by stimulating the median nerve at elbow, medial to the brachial artery. Distance between the two stimulating cathodes was measured and the conduction velocity calculated by dividing this distance by the difference between proximal and distal latencies.

Median nerve sensory conduction: The active and reference electrodes were placed 4 cm apart over the middle finger of the dominant hand and the ground was placed over the palmar aspect at wrist. The distal and proximal latencies were recorded by stimulating the median nerve 14 cm proximal to the active electrode at wrist and near brachial artery at elbow, respectively; and the velocity was calculated by measuring the distance between them.

Electromyography: The surface EMG from frontalis muscle of the forehead and biceps of the dominant hand were studied. To evaluate the muscle relaxation and the muscle strength, two surface electrodes were fixed on the muscle of the subject. EMG was recorded after 5 min supine rest and during maximal voluntary contraction of the muscle. The maximum amplitude of the raw EMG was determined. Mean values of the amplitude of the compound motor action potential (CMAP) were compared before and after yoga training.

Visual evoked potential (VEP): The visual evoked potential study was performed according to the method adopted by Aminoff.^[18] The recording electrode was placed at Oz as per the 10-20 international system of EEG electrode placement. The reference electrode was placed at Fpz and the ground electrode at the back of right ear. The pattern reversal visual stimulus was given from a monitor kept 1.2 m away from the subject. P100 latency was recorded by giving the stimuli at a rate of 1 Hz, 128 averaging and two trials were done for each eye.

Reaction time

ART and VRT were measured on a digitalized reaction time apparatus (Anand Agencies, Pune, India) by instructing the subject to lift his finger from the key in response to a sound or light stimulus. The visual and auditory signals were given from the front of the subject who was instructed to use his dominant hand while responding to the signal. The subject's response was obtained from the electronic readings. Red and green discrimination time recordings were performed by asking the subject to release the key related to the respective color. At least ten trials were recorded for each measurement and mean of three similar

observations was taken as a single value for statistical analysis. All subjects were previously assessed for colour blindness and none failed the test.

Analysis of data

In all the groups, the above mentioned parameters were measured at the beginning and again at the end of the 6 months study period. The data was analyzed using paired t-test to compare the pre- and post-training values of each group. Comparisons between groups were made by one-way analysis of variance (ANOVA) followed by Tukey's test. When data were non-homogeneously distributed, Kruskal-Wallis test followed by Dunn's test were used. A two-tailed $P < 0.05$ was considered significant.

RESULTS

The results are given in Tables 1-5. There was increase in the total integral (power) of all the groups in both eyes open and eyes closed EEG [Tables 1 and 2]. On intergroup comparison, delta % was significantly ($P < 0.05$) higher in the asan-pranayama as compared to the pranayama group. Alpha and theta integrals increased in all the three yoga groups, and this was significant ($P < 0.05$) for alpha integral in asan and asan-pranayama groups, and theta integral in pranayama and asan-pranayama groups. Post-training theta integral of asan and pranayama groups was significantly ($P < 0.05$) higher than the control group. The standardized distal motor latency of median nerve reduced significantly ($P < 0.05$) in asan and asan-pranayama group, though the standardized distal latency of median nerve decreased in all the yoga groups [Table 3], it was statistically insignificant. The resting EMG of frontalis muscle decreased in all the yoga groups [Table 3] and this was significant ($P < 0.01$) in pranayama group. On

intergroup comparison, post-training EMG amplitude of resting frontalis muscle in asan-pranayama group was significantly ($P < 0.05$) lower than corresponding value of asan group. There was no change in latency, but amplitude showed a decrease in all the three yoga groups and this was significant ($P < 0.05$) in asan-pranayama group [Table 4]. P100 increased significantly ($P < 0.01$) on the left side in the asan group. There was a post-training decrease in RT in all the yoga groups [Table 5] and this was significant for VRT in asan group, ART in pranayama group, and VRT as well as ART in the asan-pranayama group ($P < 0.05$).

DISCUSSION

Electroencephalogram

In the eyes open EEG, there was an increase in the total integral (power) of all the groups [Table 1]. In the asan-pranayama group, the increase in the alpha and theta integral was statistically significant ($P < 0.05$). On intergroup comparison, delta % was significantly ($P < 0.05$) higher in the asan-pranayama as compared to the pranayama group. During the eyes closed EEG recordings, the training-induced increase in total power was more pronounced and statistically significant [Table 2]. Pranayama training-induced increase in total power was highly significant ($P < 0.001$) when compared to control group. There was an increase in alpha and theta integrals in all the three yoga groups, which was statistically significant ($P < 0.05$) for alpha integral in asan and asan-pranayama groups and theta integral in pranayama and asan-pranayama groups. The post-training theta integral of the asan and pranayama groups was significantly ($P < 0.05$) higher as compared to the control group. The alpha and delta waves signify synchronization of brain potentials. Yoga practice is known to relax the

Table 1: Eyes open EEG recording of Pondicherry police trainees before and after training

	Asan (N=14)		Pranayama (N=15)		Asan-pranayama (N=11)		Control (N=8)	
	B	A	B	A	B	A	B	A
Total integral	0.0036±0.0020	0.0064±0.0052	0.0051±0.0030	0.0068±0.0041	0.0016±0.0008	0.0084±0.0069	0.0018±0.0012	0.0040±0.0059
Beta integral	0.0005±0.0003	0.0009±0.0010	0.0008±0.0007	0.0014±0.0013*	0.0003±0.0002	0.0005±0.0002	0.0002±0.0001	0.0003±0.0002
Beta %	14.70±4.68	11.62±6.63	15.39±7.59	22.03±15.59	19.40±14.12	9.93±6.27*	15.76±11.35	13.01±4.70
Alpha integral	0.0012±0.0009	0.0018±0.0017	0.0014±0.0010	0.0020±0.0017	0.0004±0.0003	0.0015±0.0014*	0.0003±0.0002	0.0007±0.0008
Alpha %	31.08±13.12	28.96±16.86*	27.43±15.97	31.18±18.17	25.98±14.88	22.83±13.33	16.57±4.10	24.42±17.15
Theta integral	0.0006±0.0005	0.0015±0.0020	0.0009±0.0004	0.0008±0.0005	0.0003±0.0002	0.0013±0.0012*	0.0003±0.0002	0.0006±0.0007
Theta %	16.48±5.69	22.10±10.77	18.18±6.72	13.85±7.10	17.76±5.23	15.48±6.71	16.94±8.21	16.91±5.18
Delta integral	0.0013±0.0006	0.0022±0.0018	0.0021±0.0013	0.0023±0.0031	0.0006±0.0004	0.0051±0.0056	0.0010±0.0008	0.0023±0.0043
Delta %	37.74±12.21	37.32±18.23	38.99±13.14	31.40±17.35	36.85±13.91	51.76±15.76**	50.73±15.98	45.66±15.72

Values are expressed as mean±SD. EEG: Electroencephalogram; * $P < 0.05$ by paired t-test; ** $P = 0.025$ between groups for delta % by ANOVA with $P < 0.05$ for pranayama vs asan-pranayama by Tukey's test, $P > 0.05$ for all other comparisons

Table 2: Eyes closed EEG recording of Pondicherry police trainees before and after training

	Asan (N=14)		Pranayama (N=15)		Asan-pranayama (N=11)		Control (N=8)	
	B	A	B	A	B	A	B	A
Total integral	0.0048±0.0038	0.0083±0.0046*	0.0050±0.0056	0.0132±0.0099***	0.0023±0.0012	0.0078±0.0056*	0.0019±0.0014	0.0032±0.0020
Beta integral	0.0006±0.0005	0.0010±0.0009	0.0005±0.0005	0.0016±0.0012**	0.0004±0.0004	0.0005±0.0003	0.0002±0.0002	0.0003±0.0002
Beta %	12.00±3.72	10.87±7.15	14.11±8.15	15.54±11.18	20.00±14.94	9.88±6.84**	10.82±8.60	10.49±5.09
Alpha integral	0.0021±0.0022	0.0030±0.0026*	0.0016±0.0023	0.0066±0.0081	0.0006±0.0004	0.0017±0.0015*	0.0006±0.0007	0.0013±0.0014
Alpha %	35.38±17.96	32.59±17.28	33.56±13.73	38.20±24.41	27.76±17.63	27.00±16.00	30.26±21.32	40.79±22.94
Theta integral	0.0008±0.0006	0.0017±0.0013*	0.0011±0.0014	0.0017±0.0013**	0.0004±0.0003	0.0013±0.0011*	0.0003±0.0002	0.0005±0.0003
Theta %	17.28±5.23	21.43±10.35	20.43±6.49	15.77±10.45	19.03±5.21	16.02±4.36	17.23±10.92	15.59±6.66
Delta integral	0.0014±0.0010	0.0026±0.0019	0.0017±0.0024	0.0032±0.0033	0.0008±0.0007	0.0042±0.0038	0.0009±0.0010	0.0011±0.0010
Delta %	35.34±15.35	35.11±18.63	31.91±10.86	30.49±17.67	33.21±11.31	47.09±19.92	41.70±21.05	33.12±18.69

Values are expressed as mean±SD. EEG: Electroencephalogram; *P<0.05; **P<0.01 by paired t-test; *P<0.01 by Kruskal-Wallis test between groups with P<0.01 for pranayama vs control and asan vs control by Dunn's test

Table 3: Latency, amplitude and velocity of motor and sensory conduction in median nerve (of dominant hand) and resting EMG of right frontalis muscle in Pondicherry police trainees (Group II) before and after training

	Asan (N=7)		Pranayama (N=8)		Asan-pranayama (N=8)		Control (N=5)	
	B	A	B	A	B	A	B	A
Motor conduction								
Lat (ms)	4.26±0.73	4.06±0.61*	3.96±0.34	3.81±0.32	3.96±0.15	3.72±0.22***	3.87±0.47	3.68±0.30
Amp (mV)	8.83±3.64	8.87±3.00	9.06±1.50	9.21±1.85	10.41±2.36	9.60±2.72	10.02±1.87	9.84±1.72
V (m/s)	53.41±10.58	53.34±11.18	57.76±1.92	56.76±2.56	58.18±3.74	56.81±2.30	57.56±2.60	55.76±3.95
Sensory conduction								
Lat (ms)	3.79±0.45	3.59±0.64	3.50±0.31	3.23±0.13	3.42±0.18	3.11±0.43	3.28±0.36	3.20±0.17
Amp (V)	53.12±26.26	46.20±20.77	57.21±19.85	49.16±8.79	54.69±14.39	33.78±8.50**	46.56±10.55	51.52±8.74**
V (m/s)	54.50±3.22	59.08±4.27	57.60±2.20	55.68±3.68	57.41±2.53	56.44±3.36	58.80±2.09	58.24±1.87
EMG (V)	19.29±5.35	13.29±7.96	25.00±5.98	12.50±4.63**	21.25±4.43	15.94±6.81	16.00±4.18	16.00±5.82

Values are expressed as mean±SD. *P<0.05; **P<0.01; ***P<0.001 by paired t-test. *P=0.03 by ANOVA between groups with P<0.05 for asan vs control by Tukey's test

Table 4: Latency, P100 and amplitude of visual evoked potential of Pondicherry police trainees (Group II) before and after training

	Asan (N=7)		Pranayama (N=8)		Asan-pranayama (N=8)		Control (N=5)	
	B	A	B	A	B	A	B	A
Lat (ms)								
Left	72.71±3.19	72.94±1.84	72.55±3.06	73.87±1.31	75.30±2.78	74.10±4.14	73.68±1.42	74.60±5.32
Right	73.06±3.18	74.54±4.06	73.70±1.92	77.60±8.96	73.47±3.98	75.45±4.80	73.56±1.44	73.35±3.15
P100								
Left	98.37±2.28	99.57±1.76**	99.53±3.41	99.27±3.23	97.70±3.44	98.05±3.33	97.68±5.09	97.72±6.78
Right	100.51±4.09	97.49±2.88	99.03±2.97	99.47±2.59	98.37±2.95	98.20±3.62	97.48±2.15	97.36±3.99
Amp (V)								
Left	7.24±2.72	6.51±1.98	8.36±3.37	7.01±2.57	6.42±1.83	4.93±1.90*	6.23±1.13	6.64±2.04
Right	8.15±2.02	6.42±1.75	6.54±3.09	6.22±2.34	7.07±2.80	5.27±2.49	6.62±1.34	4.98±2.32

Values are expressed as mean±SD. *P<0.05; **P<0.01 by paired t-test

mind, decrease sympathetic activity, and synchronize waves. Stancak *et al.*^[20] has reported a relative increase of slower EEG frequencies and subjective relaxation resulting after pranayama. Previous studies have demonstrated EEG changes around somatosensory and parietal areas of the cerebral cortex, suggesting an affective arousal following agnisara, nauli, and bhastrika; and it was suggested that

these practices bring about such changes through strong stimulation of somatic and splanchnic receptors.^[21] The pranayama training seems to be more effective in this regard and this may be due to a prolonged and residual neuromuscular effect influencing the RT. It has also been previously suggested that forceful expirations in pranayama may be altering afferent inputs from abdominal

Table 5: Visual and auditory simple and discrimination reaction times of Pondicherry police trainees before and after training

	Asan (N=16)		Pranayama (N=16)		Asan-pranayama (N=19)		Control (N=16)	
	B	A	B	A	B	A	B	A
Simple RT								
VRT	231.23±39.13	205.29±34.85*	203.72±29.02	200.09±27.10	219.28±19.28	207.46±25.86*	222.82±29.83	214.68±24.16
ART	179.14±31.89	168.70±32.49	178.82±28.15	162.26±21.24 *	173.44±19.67	164.45±16.13*	176.69±20.34	169.54±23.75
Discrimination RT								
Red	379.75±83.95	312.58±68.49**	340.13±51.53	301.56±73.27 *	360.38±90.10	352.43±83.53	300.08±62.07	369.10±91.00*
Green	415.63±105.05	317.56±73.13**	376.44±85.29	306.00±66.26***	382.78±81.77	345.05±80.06	323.08±56.81	384.75±72.24*

Values are expressed as mean±SD. * $P < 0.05$, ** $P < 0.01$ by paired 't' test, * $P = 0.02$ by ANOVA with $P < 0.05$ for pranayama vs. control by Tukey's test

and thoracic regions which in turn modulates activity at ascending reticular activating system and thalamocortical levels.^[14]

Motor conduction

The standardized distal motor latency of median nerve reduced significantly ($P < 0.05$) in asan group at the end of 6 months training period [Table 3]. In asan-pranayama group also, training produced a significant ($P < 0.001$) reduction in standardized distal motor latency of median nerve. The amplitude of CMAP and conduction velocity of median nerve did not change significantly after yoga training in any of the three yoga groups. The decreased motor latency following yoga training can be attributed to either an increase in conduction velocity or facilitation of neuromuscular transmission. Since there was no significant change in conduction velocity in our subjects, it can be presumed that the decrease in latency is due to improved neuromuscular transmission.

Sensory conduction

Standardized distal latency of median nerve decreased in all the three yoga groups [Table 3]. However, this decrease was statistically insignificant. There was no significant change in sensory conduction velocity of the median nerve in any of the yoga groups. The decreased standardized distal sensory latency can be attributed to facilitated neuromuscular transmission following yoga training. This is an interesting finding and needs further investigation. It has been reported that short-term exercise stimulates endothelium-dependent vasodilatation and this may be one of the mechanisms by which nerve conduction is improving in our subjects. Gustaffson *et al.*^[22] have proposed that higher vascular endothelial growth factor expression during short-term exercise may play a role in increasing the endoneurial blood flow. Terjung *et al.*^[23] have reported improvements in abnormal perfusion and plasma viscosity as well as the facilitation of oxygen delivery by exercise. During exercise, blood vessels are exposed to repeated episodes of hyperemia and this stimulates increases in nitric oxide release that augments vasodilatation. Kjeldsen *et al.*^[24] have reported increases in Na/K-ATPase in rat

muscle cells following exercise and this may be one of the mechanisms behind improvements occurring in our human subjects too. The lack of any major intergroup differences may be attributed to the fact that our control group was also participating in rigorous police training that involves regular exercise.

Electromyography

The resting EMG of frontalis muscle decreased in all three yoga groups [Table 3]. This decrease was statistically significant ($P < 0.01$) in pranayama group. On intergroup comparison by ANOVA, the post-training EMG amplitude of the resting frontalis muscle in the asan-pranayama group was found to be significantly ($P < 0.05$) lower than the corresponding value of the asan group. The decrease in resting EMG amplitude can be explained on the basis of the common observation that yoga practice produces psychosomatic relaxation. This is consistent with the observation of Blumenstein *et al.*^[25] that relaxation techniques lead to a decrease in frontalis EMG amplitude. The maximum EMG during voluntary muscular contraction did not change significantly in any of the three yoga groups after training. This can be explained on the basis of the fact that maximum EMG during voluntary muscular contraction is proportional to the functional muscle mass and 6 months of yoga training of moderate intensity did not increase muscle mass in our subjects. In this context it is important to remember that our subjects were also undergoing police training which was quite intense.

Visual evoked potential

There was no change in latency, but amplitude showed a decrease in all three yoga groups and this decrease was significant ($P < 0.05$) in the asan-pranayama group [Table 4]. P100 increased significantly ($P < 0.01$) on the left side in the asan group. There was no change in P100 in the other groups. However, as VEP amplitude may be influenced by a number of variables,^[18] it cannot be commented upon.

Reaction time studies

The effect of yoga training on RT is given in Table 5. The

baseline values of VRT as well as ART were comparable in all the four groups. In all the groups, ART was shorter than VRT and this is consistent with our earlier findings.^[11] Yoga training produced a decrease in RT in all the three groups. This decrease was statistically significant for VRT in asan group, ART in pranayama group and VRT as well as ART in the asan-pranayama group ($P < 0.05$). In the control group, there was no significant change in VRT or ART. Red-green discrimination RT decreased in all the three yoga groups after the 6-month training period. This decrease was statistically significant for red-green discrimination RT in the asan group ($P < 0.001$), red discrimination RT for pranayama group ($P < 0.05$), and green discrimination RT in the pranayama group ($P < 0.001$). In contrast to the yoga group, there was a significant ($P < 0.05$) increase in red as well as green discrimination RT in the control group. A decrease in RT indicates an improved sensorimotor performance and an enhanced processing ability of the central nervous system (CNS). This indicates (i) greater alertness and faster rate of information processing and, (ii) improved ability to concentrate and less distractibility.^[11,14] Yoga is also known to decrease mental fatigability and increase performance quotient.^[26] Decrease in RT signifies an improvement in central neuronal processing ability and this may be attributed to greater arousal and faster rate of information processing along with improved concentration. RT is related to the level of arousal and it has been reported that RT is fastest with an intermediate level of arousal and deteriorates when subjects are either too relaxed or too tensed.^[27] Exercise has been shown to improve RT and it has been reported that moderate muscular tension shortened pre-contraction RT and that isometric contraction allows the brain to work faster.^[28-30] With the above in mind, we can attribute the faster reactivity of our subjects following yoga training to an intermediate level of arousal brought about by a conscious synchronization of dynamic muscular movements with slow, regular, and deep breathing. The present study confirms that yoga training leads to a significant reduction in visual, auditory as well as discriminatory RT. Measurement of RT, which is an indirect index of the processing ability of CNS is simple to perform and requires inexpensive apparatus. Hence, RT can be used as a simple, quantitative, objective, and non-invasive method for monitoring the beneficial effects of yoga training.

As Ramamurthi^[9] suggested in his review, yogic control of sub-cortical networks between voluntary (cerebral cortex) and involuntary (medullary centers) areas of brain may induce special functions (*siddhis*) that cannot be quantified or explained within the parameters of present-day science. However, through efforts such as ours, we may be able to study and report on some apparent effects resulting from training in asan and pranayama in normal subjects for a limited time using non-invasive laboratory techniques. Hence, we conclude by reiterating that even a limited span of yogic training can transform the personality of a human

being into a better one while also modifying the above-mentioned neurophysiological functions beneficially.

The main limitation of our study is our inability to do all the electrophysiological tests in all the participants due to the time consuming nature of the electrophysiological testing, tight schedule of our labs that also cater to hospital patients, and the inability of our subjects to come to the lab on more than two occasions (pre- and post-testing). The fact that our subjects were simultaneously undergoing rigorous police training has compounded the neurophysiological changes as evidenced in the control group as well as the three yoga groups. It is suggested that further detailed studies be done on a larger population to confirm these findings and facilitate a deeper understanding of the mechanisms underlying such neurophysiological changes.

SUMMARY AND CONCLUSION

Police trainees showed beneficial effects of yoga training, although they were undergoing intensive police training and the yoga training was relatively less intense. Alpha, theta and total power of EEG increased as a result of asan training. A shortening of visual reaction time and a decrease in red-green discriminatory reaction time signifies an improved and faster processing of visual input. They also showed a decrease in resting EMG voltage signifying better muscular relaxation following pranayama training. Beta, theta, and total power of EEG increased; while ART and red-green discriminatory reaction times decreased in the trainees, signifying a more alert state as well as improved central neural processing. A combination of asan and pranayama training for 6 months produced an improvement in motor and sensory nerve conduction. Total power of EEG, alpha, and theta power as well as delta % increased while reaction time decreased; signifying an alert and yet relaxed state of the neuromuscular system.

The present study has shown that 6 months training in asan, pranayama as well as their combination is effective in improving physiological functions of police trainees who showed beneficial effects of yoga training, although they were undergoing intensive police training and the yoga training was relatively less intense. Hence, we recommend that yoga training be introduced in police training curricula.

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