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A scholarly attempt was made by the investigator to study the relevant literature and research pertaining to the study highlighting the several aspects, widening the horizon and body of knowledge on the subject. The most critical literatures have been systematically documented in the preceding part of this chapter following which conclusions drawn from the review of the related literature, essence of the review of the related literature have been documented.

2.1. Effect of Kapalbhati on Autonomic Nervous System

A study was done by Kennedy et al. (1993)\(^1\) on the effects of unilateral forced nostril breathing on the heart. Three experiments were done that employ impedance cardiography to monitor the effects of unilateral forced nostril breathing (UFNB) on the heart. Experiment one includes seven subjects (four males, three females) with a respiratory rate of six breaths per minute (BPM). Experiment two includes 16 trials using one subject to examine the intraindividual variability, at six BPM. Experiment three includes ten trials with the same subject in experiment two, but with a respiratory rate of two to three breaths/s. This rapid rate of respiration is a yogic breathing technique called “breath of fire” or “kapalabhati” and employs a very shallow but rapid breath in which the abdominal region acts like a bellows. It was found that all three experiments demonstrated that right UFNB increases heart rate (HR) compared to left. Experiment one gave seven negative slopes, or lowering in HR with left nostril breathing and seven positive slopes, or increases in HR with right nostril breathing, \(p = .001\). The second and third experiments showed differences in HR means in which right UFNB increases HR more than left, \(p = .013\), \(p = .001\), respectively. In experiment two stroke volume was higher with left UFNB, \(p = .045\), compensating for lower HR. Left

UFNB increased end diastolic volume as measured in both experiments one and two, $p = .006$, $p = .001$, respectively. These results demonstrate a unique unilateral effect on sympathetic stimulation of the heart that may have therapeutic value.

A study was done by Stancák et al. (1991)\(^2\) on observations on respiratory and cardiovascular rhythmicities during yogic high-frequency respiration. Yogic high-frequency respiration kapalabhati (KB) was studied in 24 subjects from a point of rhythmicity. Respiratory movements, blood pressure and R-R intervals of ECG were recorded in parallel and evaluated by spectral analysis of time series. Respiratory signals during KB were modulated by 0.1 Hz rhythm in 82% of experiments. This component was also present in R-R intervals and blood pressure during KB. Frequency (0.2-0.3 Hz) was observed in 67% of respiratory records. The presence of the component 0.2-0.3 Hz in respiration was dependent on resting respiratory frequency. This frequency component was reduced in R-R intervals but increased in blood pressure during kapalabhati as compared to that at rest. The occurrence of both frequency components in respiration during KB supports the hypothesis about the integrative role of cardiovascular and respiratory rhythms in physiological states characterized by altered respiratory frequency.

A study was done by Kuna et al. (1991)\(^3\) on Kapalabhati: Yogic cleansing exercise, cardiovascular and respiratory changes. They studied cardiovascular and respiratory changes during yogic breathing exercise kapalabhati (KB) in seventeen advanced yoga practitioners. The exercise consisted in fast shallow abdominal respiratory movements at about two Hz frequency. Blood pressure, ECG and respiration were recorded continuously during three five minute periods of KB and during pre and post KB resting periods. The beat-to-beat series of systolic blood pressure (SBP) and diastolic blood pressure (DBP), R-R intervals and respiration were analysed by spectral

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analysis of time series. The mean absolute power was calculated in three frequency bands—band of spontaneous respiration, band of 0.1 Hz rhythm and the low-frequency band greater than 15s in all spectra. The mean modulus calculated between SBP and R-R intervals was used as a parameter of baroreceptor-cardiac reflex sensitivity (BRS).

It was found that heart rate increased by nine beats per minute during KB. SBP and DBP increased during KB by 15 and 6 mmHg respectively. All frequency bands of R-R interval variability were reduced in KB. Also the BRS parameter was reduced in KB. The amplitude of the high-frequency oscillations in SBP and DBP increased during KB. The low-frequency blood pressure oscillations were increased after KB. The results point to decreased cardiac vagal tone during KB which was due to changes in respiratory pattern and due to decreased sensitivity of arterial baroreflex. Decreased respiratory rate and increased SBP and low-frequency blood pressure oscillations after KB suggest a differentiated pattern of vegetative activation and inhibition associated with KB exercise.

The heart rate variability (HRV) is an indicator of the cardiac autonomic control. Two spectral components are usually recorded, viz. high frequency (0.15-0.50 Hz), which is due to vagal efferent activity and a low frequency component (0.15-0.50 Hz), due to sympathetic activity.

2.2. Effect of Kapalbhati on Different Physiological Variables

A study was done by Gharote (1990) on effect of kapalabhati on blood urea, creatinine and tyrosine. The study conducted on twelve normal healthy male subjects showed decrease in blood urea, increase in creatinine and tyrosine after one minute of kapalabhati, a fast-breathing technique of hatha yoga [120 respiratory strokes (minute)]. It was found that, from biochemical point of view the practice of kapalabhati seems to promote decarboxylation and oxidation mechanisms due to which quieting of respiratory centres is achieved, which is also the prerequisite for the practice of pranayama, another important technique of yoga.

A study was done by M. Kuna et al. (1991)\textsuperscript{5} on kapalabhati: yogic cleansing exercise. EEG topography analysis. Topography of brain electrical activity was studied in 11 advanced yoga practitioners during yogic high-frequency breathing kapalabhati (KB). It was found that Alpha activity was increased during the initial five minute of KB. Theta activity mostly in the occipital region was increased during later stages of 15 minute KB compared to the pre-exercise period. Beta one activity increased during the first 10 minute of KB in occipital and to a lesser degree in parietal regions. Alpha and beta one activity decreased and theta activity was maintained on the level of the initial resting period after KB. The score of general deactivation factor from activation deactivation adjective checklist was higher after KB exercise than before the exercise. The results suggest a relative increase of slower EEG frequencies and relaxation on a subjective level as the after effect of KB exercise.

A study was done by Joshi and Telles (2008)\textsuperscript{6} on “a nonrandomized non-naive comparative study of the effects of kapalabhati and breath awareness on event-related potentials in trained yoga practitioners” The objective of the study was to compare the P300 event-related potentials recorded before and after (1) high-frequency yoga breathing (HFYB) and (2) breath awareness. The P300 was recorded in participants of two groups before and after the intervention session (one minute in duration). All participants were receiving yoga training in a residential yoga center, Swami Vivekananda Yoga Research Foundation in Bangalore, India. Thirty (30) male participants formed two groups (n = 15 each) with comparable ages (within an age range of 20–35 years) and comparable experience of the two techniques, the minimum experience being three months. The two groups were each given a separate intervention. One group practiced a HFYB at a frequency of approximately 2.0 Hz, called kapalabhati. The other group practiced breath awareness during which participants were aware of their breath while seated, relaxed. The P300 event-related potential, which is generated when attending to and discriminating between auditory stimuli, was recorded.

before and after both techniques. It was found that P300 peak latency decreased after HFYB and the P300 peak amplitude increased after breath awareness.

Hence it was concluded that both practices (HFYB and Breath awareness), though very different, influenced the P300. HFYB reduced the peak latency, suggesting a decrease in time needed for this task, which requires selective attention. Breath awareness increased the P300 peak amplitude, suggesting an increase in the neural resources available for the task.

2.3. Effect of Anulom Vilom and Nadishodhana Pranayama on Autonomic Nervous System

A study was done by Nagarathna et al. (1996) on physiological measures of right nostril breathing. This study was conducted to assess the physiological effects of a yoga breathing practice that involves breathing exclusively through the right nostril. This practice is called surya anuloma viloma pranayama (SAV). Twelve volunteers (average age 27.2 years +/- 3.3 years, four males) were assessed before and after test sessions conducted on two consecutive days. On one day the test session involved practicing SAV pranayama for 45 minutes (SAV session). During the test period of the other day, subjects were asked to breathe normally for 45 minutes (NB session). For half the patients (randomly chosen) the SAV session was on the first day and the NB session on the next day. For the remaining six patients, the order of the two sessions was reversed.

After the SAV session (but not after the NB) there was a significant (P < .05, paired t test) increase in oxygen consumption (17%) and in systolic blood pressure (mean increase 9.4 mm Hg) and a significant decrease in digit pulse volume (45.7%). The latter two changes are interpreted to be the result of increased cutaneous vasoconstriction. After both SAV and NB sessions, there was a significant decrease in skin resistance (two factor ANOVA, Tukey test). These findings showed that SAV has a sympathetic stimulating effect. This technique and other variations of unilateral forced nostril breathing deserve further study regarding therapeutic merits in a wide range of disorders.

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A study was done by Bhargava, Gogate, and Mascarenhas (1988) on autonomic responses to breath holding and its variations following pranayama. Autonomic responses to breath holding were studied in twenty healthy young men. Breath was held at different phases of respiration and parameters recorded were breath holding time, heart rate systolic and diastolic blood pressure and galvanic skin resistance (GSR). After taking initial recordings all the subjects practised nadi-shodhana pranayama for a period of four weeks. At the end of four weeks same parameters were again recorded and the results compared.

Baseline heart rate and blood pressure (systolic and diastolic) showed a tendency to decrease and both these autonomic parameters were significantly decreased at breaking point after pranayamic breathing. Although the GSR was recorded in all subjects the observations made were not conclusive. Thus pranayama breathing exercises appear to alter autonomic responses to breathe holding probably by increasing vagal tone and decreasing sympathetic discharges.

A study was done by Raghuraj and Telles the effect of right, left, and alternate nostril yoga breathing (i.e., RNYB, LNYB, and ANYB, respectively) were compared with breath awareness (BAW) and normal breathing (CTL). Autonomic and respiratory variables were studied in twenty one male volunteers with ages between 18 and 45 years and experience in the yoga breathing practices between three and forty eight months. Subjects were assessed in five experimental sessions on five separate days. The sessions were in fixed possible sequences and subjects were assigned to a sequence randomly. Each session was for 40 minutes; 30 minutes for the breathing practice, preceded and followed by five minutes of quiet sitting. Assessments included heart rate variability, skin conductance, finger plethysmogram amplitude, breath rate, and blood pressure.

Following RNYB there was a significant increase in systolic, diastolic and mean pressure. In contrast, the systolic and diastolic pressure decreased after ANYB and the

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systolic and mean pressure were lower after LNYB. Hence, unilateral nostril yoga breathing practices appear to influence the blood pressure in different ways. These effects suggest possible therapeutic applications.

Practice of pranayama has been known to modulate cardiac autonomic status with an improvement in cardio-respiratory functions. Keeping this in view Subbalakshmi et al. (2005) designed the study to determine whether nadi-shodhana pranayama practice for 20 minutes has any immediate effect on heart rate, systolic and diastolic blood pressure, peak expiratory flow rate and simple problem solving ability. Ten normal healthy subjects of first year physiotherapy course volunteered for this study. They were ranged between 17-20 years among them, five were females and five were males. They did not have any previous training in pranayama. They were highly motivated to participate in this program. Study procedures were done separately for each subject at the same time of the day between four to five pm. All the selected physiological parameters were measured before and after performing nadi-shodhana pranayama. Two sets of controls were done in the matched subjects by allowing them to relax in a couch (A) or close their eyes with quiet breathing for 20 minutes. Following nadi-shodhana pranayama of 20 minutes, a significant decline in basal heart rate (P<0.0001) and systolic pressure (P<0.001) was observed. Peak expiratory flow rate was significantly improved (P<0.01) and the time taken for simple problem solving was significantly less following pranayama practice (P<0.0001). In contrast both control subjects did not show any significant change in respiratory and cardiovascular parameters with 20 minutes. The study suggested that the nadi-shodhana pranayama rapidly alters cardiopulmonary responses and improves simple problem solving. Further studies on a larger size need to illustrate the underlying mechanisms involved in this alteration.

The response of right nostril breathing (RNB) and left nostril breathing (LNB) on cardio-respiratory and autonomic functions were investigated by Jain, Srivastava and Singhal (2005) in healthy student’s volunteers of both sexes. The RNB and LNB


groups comprised of ten males and ten females in each in age range of 17-22 years. Initially, in both groups control values of respiratory rate (RR), heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), peak expiratory flow rate (PEFR) and galvanic skin resistance (GSR) were recorded. The same parameters were recorded after 15 minutes (acute exposure) and 8 weeks of training in RNB and LNB.

In males RR (P<0.0001), SBP (P<0.05) fell significantly after 15 minutes of RNB. After eight weeks training RNB, HR (P<0.05) decreased, SBP (P<0.001) declined more profoundly and RR (P<0.0001) and DBP (P<0.05) decrement was maintained. After 15 minutes of LNB, RR (P<0.01), HR (P<0.01), SBP (P<0.001) and DBP (P<0.01) declined significantly, on eight weeks training, RR (P<0.0001) and HR (P<0.001) decreased further, the decrement in SBP (P<0.01) was the same.

In females, RR alone fell significantly (P<0.05) after 15 minutes RNB. After eight weeks RR decrement was more profound (P<0.0001) and DBP also declined significantly (P<0.01). Similarly, 15 minutes LNB resulted in significant reduction in RR (P<0.001) and HR (P<0.0001) only. Following eight weeks, of training in LNB, in addition to RR (P<0.0001) and HR (P<0.05) decrement, SBP (P<0.01) and DBP (P<0.05) also fell significantly.

Both in males and females, GSR did not change significantly (P>0.05) either after RNB and LNB (15 minutes/ 8weeks). PEFR rose significantly (P<0.05) only in females after eight weeks of LNB.

The results suggest that there are no sharp distinctions between effects of RNB and LNB either acute exposure (15 minutes) or after training (eight weeks). However, there is a general parasympathetic dominance evoked by both these breathing pattern.

2.4. Studies on Breathing, Relaxation, Meditation and Autonomic Nervous System

A study was done by Takeuchi and Hayano (1994)\textsuperscript{12} on effects of relaxation training on cardiac parasympathetic tone. To examine the hypothesis that the relaxation

response is associated with an increase in cardiac parasympathetic tone, the frequency
components of heart rate variability during relaxation training were investigated in 16
college students. Electrocardiograms and pneumograms were recorded during a five
minutes baseline period followed by three successive five minutes sessions of the
autogenic training (relaxation) or by the same periods of quiet rest (control), while
subjects breathed synchronously with a visual pacemaker (0.25 Hz).

It was found that neither the magnitude nor the frequency of respiration showed
a significant difference between relaxation and control, the amplitude of the high-
frequency component of heart rate variability increased only during relaxation (p = .008). There was no significant difference in the ratio of the low-frequency (0.04–0.15
Hz) to the high-frequency amplitudes. The increased high-frequency amplitude without
changes in the respiratory parameters indicates enhanced cardiac parasympathetic tone.

Hence it was concluded that enhanced cardiac parasympathetic tone may
explain an important mechanism underlying the beneficial effect of the relaxation
response.

A study was done by Travis et al. (2001) on autonomic and EEG patterns
distinguish transcending from other experiences during transcendental meditation
practice. The study compared EEG and autonomic patterns during transcending to
“other” experiences during transcendental meditation (TM) practice. To correlate
specific meditation experiences with physiological measures, the experimenter rang a
bell three times during the TM session. Subjects categorized their experiences around
each bell ring.

Transcending, in comparison to “other” experiences during TM practice, was
marked by: (1) significantly lower breath rates; (2) higher respiratory sinus arrhythmia
amplitudes; (3) higher EEG alpha amplitude; and (4) higher alpha coherence. In
addition, skin conductance responses to the experimenter-initiated bell rings were larger
during transcending. Hence it was concluded that monitoring patterns of physiological

13 Travis, Frederick, “Autonomic and EEG Patterns Distinguish Transcending from other
Experiences during Transcendental Meditation Practice”, International Journal of
variables may index dynamically changing inner experiences during meditation practice. This could allow a more precise investigation into the nature of meditation experiences and a more accurate comparison of meditation states with other eyes-closed conditions.

A study was done by Corby, James, Roth, Zarcone, and Kopell (1984)\textsuperscript{14} on psychophysiological correlates of the practice of tantric yoga meditation. Autonomic and electroencephalographic (EEG) correlates of tantric yoga meditation were studied in three groups of subjects as they progressed from normal consciousness into meditation. Groups differed in their level of meditation proficiency. Measures of skin resistance, heart rate, respiration, autonomic orienting responses, resting EEG, EEG alpha and theta frequencies, sleep-scored EEG, averaged evoked responses, and subjective experience were employed. Unlike most previously reported meditation studies, proficient meditators demonstrated increased autonomic activation during meditation while unexperienced meditators demonstrated autonomic relaxation. During meditation, proficient meditators demonstrated increased alpha and theta power, minimal evidence of EEG-defined sleep, and decreased autonomic orienting to external stimulation.

An episode of sudden autonomic activation was observed that was characterized by the meditator as an approach to the yogic ecstatic state of intense concentration. These findings challenge the current “relaxation” model of meditative states.

A study was done by Wallace (1999)\textsuperscript{15} on autonomic and EEG patterns during eyes-closed rest and transcendental meditation (TM) practice: The basis for a neural model of TM practice. In this single-blind within-subject study, autonomic and EEG variables were compared during 10 minute, order-balanced eyes-closed rest and transcendental meditation (TM) sessions. TM sessions were distinguished by (1) lower breath rates, (2) lower skin conductance levels, (3) higher respiratory sinus arrhythmia levels, and (4) higher alpha anterior-posterior and frontal EEG coherence. Alpha power

\textsuperscript{14} Corby, C., James, Walton T. Roth, Jr., Vincent P. Zarcone, and Bert S. Kopell, “Psychophysiological Correlates of the Practice of Tantric Yoga Meditation”, \textit{Archives of General Psychiatry}, May 1978, 35(5):571-580.

was not significantly different between conditions. These results were seen in the first minute and were maintained throughout the 10 minute sessions. TM practice appears to (1) lead to a state fundamentally different than eyes-closed rest; (2) result in a cascade of events in the central and autonomic nervous systems, leading to a rapid change in state (within a minute) that was maintained throughout the TM session; and (3) be best distinguished from other conditions through autonomic and EEG alpha coherence patterns rather than alpha power. Two neural networks that may mediate these effects are suggested. The rapid shift in physiological functioning within the first minute might be mediated by a “neural switch” in prefrontal areas inhibiting activity in specific and nonspecific thalamocortical circuits. The resulting “restfully alert” state might be sustained by a basal ganglia-corticothalamic threshold regulation mechanism automatically maintaining lower levels of cortical excitability.

A study was done by Kubota, Sato, Toichi, Murai, Okada, Hayashi and Sengoku (2001)\textsuperscript{16} on frontal midline theta rhythm is correlated with cardiac autonomic activities during the performance of an attention demanding meditation procedure. Frontal midline theta rhythm (Fm theta), recognized as distinct theta activity on EEG in the frontal midline area reflects mental concentration as well as meditative state or relief from anxiety. Attentional network in anterior frontal lobes including anterior cingulate cortex is suspected to be the generator of this activity, and the regulative function of the frontal neural network over autonomic nervous system (ANS) during cognitive process is suggested.

In the conducted study, a standard procedure of zen meditation requiring sustained attention and breath control was employed as the task to provoke Fm theta and simultaneous EEG and ECG recordings were performed. For the subjects in which Fm theta activities were provoked (six men, six women, 48% of the total subjects), peripheral autonomic activities were evaluated during the appearance of Fm theta as well as during control periods. Successive inter-beat intervals were measured from the ECG and a recently developed method of analysis by Toichi et al. (J. Auton. Nerv. Syst.

62 (1997) 79-84) based on heart rate variability was used to assess cardiac sympathetic and parasympathetic functions separately.

It was found that both sympathetic and parasympathetic indices were increased during the appearance of Fm theta compared with control periods. Theta band activities in the frontal area were correlated negatively with sympathetic activation. The results suggest a close relationship between cardiac autonomic function and activity of medial frontal neural circuitry.”

A study was done by Wallace (1997)\textsuperscript{17} on autonomic patterns during respiratory suspensions. In two experiments, they investigated physiological correlates of transcendental consciousness during transcendental meditation sessions. In the first, experimenter initiated bells, based on observed physiological patterns, marked three phases during a transcendental meditation session in 16 individuals. Interrater reliability between participant and experimenter classification of experiences at each bell was quite good. During phases including transcendental consciousness experiences, skin conductance responses and heart rate deceleration occurred at the onset of respiratory suspensions or reductions in breath volume. In the second experiment, this autonomic pattern was compared with that during forced breath holding. Phasic autonomic activity was significantly higher at respiratory suspension onset than at breath holding onset. These easily measured markers could help focus research on the existence and characteristics of transcendental consciousness.

2.5. \textbf{Studies on Breathing, Relaxation, Meditation, Heart Rate Variability and Brain Activity}

Shaw and Jain (2009)\textsuperscript{18} investigated the effect of progressive relaxation training on heart rate variability (criterion variable) of high and low mental ability sportspersons with extreme extroversion and neuroticism scores. The subjects were 210 male sportspersons randomly selected from the University of Delhi with age ranging from 19

\begin{footnotesize}
\begin{itemize}
\item Dhananjoy Shaw and Abha Jain, “Effect of Progressive Relaxation Training on HRV Activity of Sportspersons in Relation to Mental Ability and Personality Dimensions”, \textit{Proceedings: India International Congress in Sports Psychology}, LNUPE, Gwalior, India2009,144-149.
\end{itemize}
\end{footnotesize}
to 21 years. The subjects were grouped as extroversion with high mental ability, introversion with low mental ability and neuroticism with low mental ability.

For the purpose of the study the variables were psychological variables (extroversion, introversion, neuroticism and mental ability), treatment variables [progressive relaxation training (PRT) aided with electro- cardiograph biofeedback (ECG-BF] and observational/ criterion variables [heart rate variability (HRV) at first, second and third minute at test one, two and three]. The study was of six week experimental paradigm, where PRT was administered for twenty minutes per session i.e. three sessions each week. The recording of HRV was performed by adopting standardized neuro-physiological protocol. Mean, standard deviations, range percentiles, ANOVA (one way) and LSD as post hoc analysis of variance were computed to analyze the data. It was concluded that the heart rate variability (HRV) measurements to assess mental trainability by progressive relaxation training (PRT) were found to be useful.

A study was done by Satyanarayana et al. (1992) on effect of santhi kriya on certain psychophysiological parameters: A preliminary study. Santhi kriya is a mixture of combined yogic practices of breathing and relaxation. Preliminary attempts were made to determine the effect of santhi kriya on certain psychophysiological parameters. Eight healthy male volunteers of the age group 25.9 +/- 3 (SD) years were subjected to santhi kriya practice daily for 50 minutes for 30 days. The volunteer’s body weight, blood pressure, oral temperature, pulse rate, respiration, ECG and EEG were recorded before and after the practice on the first day and subsequently on 10th, 20th and 30th day of their practice. They were also given a perceptual acuity test to know their cognitive level on the first day and also at the end of the study i.e., on the 30th day.

Results indicate a gradual and significant decrease in the body weight from first to 30th day (P less than 0.001) and an increase in alpha activity of the brain (P less than 0.001) during the course of 30 days of santhi kriya practice.

Increase of alpha activity both in occipital and pre-frontal areas of both the hemispheres of the brain denotes an increase of calmness. The study also revealed that santhi kriya practice increases oral temperature by three degrees F and decreases respiratory rate significantly (P less than 0.05) on all practice days. Other parameters were not found to be altered significantly. It was concluded that the santhi kriya practice for 30 days reduces body weight and increases calmness.

Friedman and Lisa (2002) done a study on zen breath meditation awareness improves heart rate variability in patients with coronary artery disease. The study examined whether patients with documented coronary artery disease would be able to learn a self-help skill which would reduce cardiac reactivity during mildly stressful and restful activities. Cardiac stress was determined measuring heart rate variability (HRV), an indication of autonomic arousal. HRV has been shown to be a predictor of sudden cardiac death in patients with cardiac disease. 56 patients with documented coronary artery disease were randomized to receive either a cardiac stress management video or a meditation video which guided them through a standard zen breath awareness meditation. The technique involved becoming attentionally absorbed in the breath, but not manipulating it. Patients HRV (SDNN) was measured during several conditions including rest, reading, paced breathing, stroop color word conflict stressor, post stressor rest, post stressor reading, and post stressor paced breathing.

It was found that patients who received meditation instruction significantly increased heart rate variability post intervention compared to patients who received a stress management lecture (p ≤ .007). In addition, patients who engaged in meditation practice handled stress better, as indicated by an increase in heart rate variability during the stroop task (p ≤ .042) and post-intervention pre-stressor paced breathing period (p ≤ .006).

Results suggest that engaging in even one brief period of zen breath meditation awareness can be effective for improving the heart’s response to stress for patients with coronary artery disease.

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Chapter II

Review of the Related Literature

Sasaki and Saito (1999)\textsuperscript{21} did a study on zazen and cardiac variability. The objective of the study was to examine the effects of “tanden breathing” by zen practitioners on cardiac variability. Tanden breathing involves slow breathing into the lower abdomen. Eleven zen practitioners, six rinzai and five soto, were each studied during 20 minutes of tandem breathing, preceded and followed by five minute periods of quiet sitting. During this time, we measured heart rate and respiration rate.

It was found that for most subjects, respiration rates fell to within the frequency range of 0.05 to 0.15 Hz during tandem breathing. Heart rate variability significantly increased within this low-frequency range but decreased in the high-frequency range (0.14–0.4 Hz), reflecting a shift of respiratory sinus arrhythmia from high-frequency to slower waves. Rinzai practitioners breathed at a slower rate and showed higher amplitude of low frequency heart rate waves than observed among soto zen participants. One rinzai master breathed approximately once per minute and showed an increase in very-low frequency waves (<0.05 Hz). Total amplitude of heart rate oscillations (across frequency spectra) also increased. More experienced Zen practitioners had frequent heart rhythm irregularities during and after the nadir of heart rate oscillations (i.e., during inhalation).

It was concluded that that increased oscillation amplitude during slow breathing is caused by resonance between cardiac variability caused by respiration and that produced by physiological processes underlying slower rhythms. The rhythm irregularities during inhalation may be related to inhibition of vagal modulation during the cardio acceleratory phase. It is not known whether they reflect cardiopathology.

A study was done by Halámek et al. (2003)\textsuperscript{22} on variability of phase shift between blood pressure and heart rate fluctuations: A marker of short-term circulation control. They postulated that the variability of the phase shift between blood pressure and heart rate fluctuation near the frequency of 0.10 Hz might be useful in assessing autonomic circulatory control. They tested this hypothesis in four groups of subjects: 28

\textsuperscript{22} Halámek, Josef, Tomá Kára et.al., “Variability of Phase Shift Between Blood Pressure and Heart Rate Fluctuations: A Marker of Short-Term Circulation Control”, \textit{Circulation}, 2003, 108:292.
young, healthy individuals; 13 elderly healthy individuals; 25 patients with coronary heart disease; and 19 patients with a planned or implanted cardioverter-defibrillator (ICD recipients). Data from five minutes of free breathing and at two different, controlled breathing frequencies (0.10 and 0.33 Hz) were used.

Clear differences (P<0.001) in variability of phase were evident between the ICD recipients and all other groups. Furthermore, at a breathing frequency of 0.10 Hz, differences in baroreflex sensitivity (P<0.01) also became evident, even though these differences were not apparent at the 0.33-Hz breathing frequency. It was concluded that the frequency of 0.10 Hz represents a useful and potentially important one for controlled breathing, at which differences in blood pressure–RR interactions become evident. These interactions, whether computed as a variability of phase to define stability of the blood pressure–heart rate interaction or defined as the baroreflex sensitivity to define the gain in heart rate response to blood pressure changes, are significantly different in patients at risk for sudden arrhythmic death. In young versus older healthy individuals, only baroreflex gain is different, with the variability of phase being similar in both groups. These measurements of short-term circulatory control might help in risk stratification for sudden cardiac death.

Shaw and Jain (2009)\textsuperscript{23} validated heart rate variability for evaluation of effects of progressive relaxation training on sportspersons with polarized personality dimensions. The subjects were 210 male sportspersons randomly selected from University of Delhi with age ranging from 19 to 21 years. For the purpose of the study the variables were psychological variables (extroversion, introversion, neuroticism and mental ability), treatment variables [progressive relaxation training (PRT) aided with electro-cardiograph biofeedback (ECG-BF)] and observational/ criterion variables [heart rate variability (HRV) at first, second and third minute at minute (1minute) and third minute (3minute) as criteria]. The groupings of the subjects were done using socio- economic scale status (G.P. Shrivastava), the general mental ability test (EGMAT: Dr. S.K. Jalota) and eysenck’s personality questionnaire (EPQ: H. J.

Eysenck’s) to obtain six experimental groups namely extroversion with high mental ability, introversion with high mental ability test, neuroticism with high mental ability, extraversion with low mental ability, introversion with low mental ability and neuroticism with low mental ability. All the selected groups were homogenous in their socio-economic status. The experiment was conducted for six weeks by administering the PRT (three sessions per week for twenty minutes of duration in each session. There were three tests namely T-1, T-2 and T-3 as pretest, posttest one and posttest two respectively. Mean, standard deviation, range, percentiles and percentage change were descriptive statistics. ANOVA (one way) and LSD as post hoc analysis of variance were computed to analyze the data. Both the selected criteria demonstrated a significant decreasing trend. The training effects of PRT on both the HRV criteria were identified demonstrated a significant decreasing trend. The training effects of PRT on both the HRV criteria were identical and collectively confirmed the effects of PRT. Thereby, it was concluded that heart rate variability (percentage change of HRV activity and reactivity due to PRT) is a valid method (criterion measures) to evaluate the effect of PRT on sportspersons with four groups of extreme personality dimensions.

2.6. Effect of Breathing Exercises and Pranayamas on Different Physical, Physiological Including Autonomic Variables

Madanmohan et al. (2005)\textsuperscript{24} planned to undertake a comparative study of the effect of short term (three weeks) training in savitri (slow breathing) and bhastrika (fast breathing) pranayamas on respiratory pressures and endurance, reaction time, blood pressure, heart rate, rate-pressure product and double product. Thirty student volunteers were divided into two groups of fifteen each. Group-I was given training in savitri pranayama that involves slow, rhythmic and deep breathing. Group- II was given training in bhastrika pranayamas, which is bellows-type rapid and deep breathing. Parameters were measured before and after three weeks of training in respiratory pressures and respiratory endurance. In both the groups, there was an appreciable but statistically insignificant shortening of reaction time. Heart rate, rate-pressure product and double product decreased in savitri pranayama group but increased significantly in

bhastrika group. It was concluded that different types of pranayamas produce different physiological responses in normal young volunteers.

A study was done by Subbalakshmi, Saxena et al. (2005)\textsuperscript{25} on immediate effect of nadi shodhana pranayama on some selected parameters of cardiovascular, pulmonary, and higher functions of brain. Practice of pranayama has been known to modulate cardiac autonomic status with an improvement in cardio-respiratory functions. Keeping this in view, the conducted study is designed to determine whether nadi-shodana pranayama practice for 20 minutes has any immediate effect on heart rate, systolic and diastolic blood pressure, peak expiratory flow rate and simple problem solving ability. Ten normal healthy subjects of first year physiotherapy course volunteered for this study. They were aged between 17-20 years. Among them, five were females and five were males. They did not have any previous training in pranayama. They were highly motivated to participate in this study program. Study procedures were done separately for each subject at the same time of the day between 4 to 5 pm. All the selected physiological parameters were measured before and after performing ‘nadi-shodhana pranayama’. Two sets of controls were done in the matched subjects by allowing them to relax in a couch (A) or close their eyes with quiet breathing for 20 minutes.

Following nadi-shodhana pranayama of 20 minutes, a significant decline in basal heart rate (P<0.0001) and systolic blood pressure (P<0.001) was observed. Peak expiratory flow rate was significantly improved (P<0.01) and the time taken for simple problem solving was significantly less following pranayama practice (P<0.0001). In contrast, both control subjects did not show any significant change in respiratory and cardiovascular parameters with 20 minutes.

The conducted study suggests that the ‘nadi-shodhana pranayama’ rapidly alters cardiopulmonary responses and improves simple problem solving. Further studies on a larger sample size need to illustrate the underlying mechanisms involved in this alteration.

A study was done by Dhungel, Malhotra et al. (2008)\(^{26}\) on effect of alternate nostril breathing exercise on cardiorespiratory functions. Pranayama (breathing exercise), one of the yogic techniques can produce different physiological responses in healthy individuals. The responses of alternate nostril breathing (ANB) the nadi sudhhi pranayama on some cardio-respiratory functions were investigated in healthy young adults. The subjects performed ANB exercise (15 minutes every day in the morning) for four weeks. Cardio-respiratory parameters were recorded before and after four weeks training period. A significant increment in Peak expiratory flow rate (PEFR L/min) and pulse pressure (PP) was noted. Although systolic blood pressure (SBP) was decreased insignificantly, the decreases in pulse rate (PR), respiratory rate (RR), diastolic blood pressure (DBP) were significant. Results indicate that regular practice of ANB (nadi sudhhi) increases parasympathetic activity.

A study was done by Pramanik, Sharma et al. (2009)\(^{27}\) on immediate effect of slow pace bhastrika pranayama on blood pressure and heart rate. The objective of this study was to evaluate the immediate effect of slow pace bhastrika pranayama (respiratory rate six breathes/minute) for five minutes on heart rate and blood pressure and the effect of the same breathing exercise for the same duration of time (five minutes) following oral intake of hyoscine-N-butylbromide (Buscopan), a parasympathetic blocker drug.

Heart rate and blood pressure of volunteers (n = 39, age = 25–40 years) was recorded following standard procedure. First, subjects had to sit comfortably in an easy and steady posture (sukhasana) on a fairly soft seat placed on the floor keeping head, neck, and trunk erect, eyes closed and the other muscles reasonably loose. The subject is directed to inhale through both nostrils slowly up to the maximum for about four seconds and then exhale slowly up to the maximum through both nostrils for about six seconds. The breathing must not be abdominal. These steps complete one cycle of slow pace bhastrika pranayama (respiratory rate six per min). During the practice the subject


is asked not to think much about the inhalation and exhalation time, but rather was requested to imagine the open blue sky. The pranayama was conducted in a cool, well-ventilated room (18–20°C). After five minutes of this breathing practice, the blood pressure and heart rate again were recorded in the aforesaid manner using the same instrument. The other group (n = 10) took part in another study where their blood pressure and heart rate were recorded following half an hour of oral intake of hyoscine-N-butylbromide 20 mg. Then they practiced the breathing exercise as stated above and the above mentioned parameters were recorded again to study the effect of parasympathetic blockade on the same pranayama.

It was noted that after slow bhastrika pranayamic breathing (respiratory rate six breathes/minute) for five minutes, both the systolic and diastolic blood pressure decreased significantly with a slight fall in heart rate. No significant alteration in both blood pressure and heart rate was observed in volunteers who performed the same breathing exercise for the same duration following oral intake of hyoscine-N-butylbromide.

It was discussed that pranayama increases frequency and duration of inhibitory neural impulses by activating pulmonary stretch receptors during above tidal volume inhalation as in Hering Bruer reflex, which bring about withdrawal of sympathetic tone in the skeletal muscle blood vessels, leading to widespread vasodilatation, thus causing decrease in peripheral resistance and thus decreasing the diastolic blood pressure. After hyoscine-N-butylbromide, the parasympathetic blocker, it was observed that blood pressure was not decreased significantly as a result of pranayama, as it was observed when no drug was administered.

Hence it was concluded that vagal cardiac and pulmonary mechanisms are linked and improvement in one vagal limb might spill over into the other. Baroreceptor sensitivity can be enhanced significantly by slow breathing (supported by a small reduction in the heart rate observed during slow breathing and by reduction in both systolic and diastolic pressure). Slow pace bhastrika pranayama (respiratory rate six per minute) exercise thus shows a strong tendency to improving the autonomic nervous system through enhanced activation of the parasympathetic system.
In a study by Raghuraj et al. (1996) among 130 right handed dominant school children in the age group of 11-18 yrs and randomly grouped them into five groups. Each group practiced different yoga technique- right nostril, left nostril, alternate nostril breathing, breathing awareness and mudras. After ten days of practice they were assessed for hand grip strengthening and lateralization. They found that the first three groups had a significant increase in the hand grip strength of both the hands ranging from 4.1%- 6.5%, where there was no change in the last two groups. This was without any change in the lateralization effect. This shows that practice of pranayama / nadi shodhana pranayama (alternative nostril breathing) increases hand grip without lateralization effect.

Hannelore korbel (1993) had done a study on five healthy young volunteers. They were given training for a period of three months in nadi shodhana pranayama and various parameters were recorded. Among them four volunteers showed stimulatory effect based on the heart rate, G.S.R and also pulse rate and air flow in the nostrils. The fifth one who was practicing nadi shodhana pranayama for a long time showed a definite change in relaxation of heart rate, pulse rate and respiratory rate and there was little change in airflow through both nostrils. This shows that relaxation of the respiratory changes can be achieved sooner, but the changes to occur in the sympathetic nervous system will take a long term practice.

In a study by Joshi et al. (1992) among 33 male and 42 female medical students of the average age of 18.5 years who underwent training for six months. The various respiratory parameters were assessed. There was decrease in the respiratory rate which they thought that it may be due to a decreased CO\textsubscript{2} production and decreased O\textsubscript{2} consumption. This produces a wake full hypo-metabolic state in the yogic group.

29 H. Korbel, “A Polygraphic Study of Nadi Suddhi Pranayama”, Yoga Theapy Instructors Course, Dissertation, in 1992 Indian Yoga Institute, Bangalore, India
In a study by Telles and Desiraju (1992)\textsuperscript{31} they observed that in pranayama there are four stages, viz. inspiratory (I), internal retention (kumbaka K-I), expiration (E) and external retention (kumbaka K-E). This has to be performed in specific ratio. Each type of pranayama has got different ratio, hence practicing them leads to variations in heart rate.

In a study by Bhargava et al. (1988),\textsuperscript{32} 20 healthy young men heart rate, systolic and diastolic blood pressure and G.S.R was recorded before they practiced nadi shodhana pranayama for a period of four weeks. At the end of four weeks, the same parameters were recorded and the results compared. Base line heart rate and blood pressure (systolic and diastolic) showed tendency to decrease and both these autonomic parameters were significantly decreased at breaking point after pranayamic breathing. Although GSR was recorded in all subjects the observations were not conclusive.

Udupa et al. (1974)\textsuperscript{33}, studied six normal young male volunteers who were undergoing training in pranayama. They found out that the pulse rate decreased more and the blood pressure did vary a bit, but there was a definite change in the autonomic functioning of the body. The breath holding time increased and at the same time the pulse rate also decreased.

In a study by Gopal et al. (1973)\textsuperscript{34}, three groups of male volunteers in the age group of 20-35 years having the same average height and weight were studied. They were divided into three groups – yogic, pranayamas, and non-yogic group and they were given training in their respective groups for six months and assessed for various cardio-respiratory parameters. When assessed after six months the yogic and the pranayamic group showed a decrease in the pulse rate in the yogic and the trained group but not very significantly.

A study was done by Udupa et al. (2003) on effect of pranayam training on cardiac function in normal young volunteers. Systolic tire intervals (STI) are non-invasive and sensitive tests for measuring the ventricular performance. It has been reported that practice of pranayam modulates cardiac autonomic status and improves cardio-respiratory functions. Keeping this in view, the conducted study was designed to determine whether pranayam training has any effect on ventricular performance as measured by STI and cardiac autonomic function tests (AFT). Twenty-four school children were randomly divided into two groups of twelve each. Group I (pranayam group) subjects were given training in nadishuddhi, mukh-bhastrika, pranav and savitri pranayams and practised the same for 20 minutes daily for a duration of three months. Group II (control group) subjects were not given any pranayama training. STI (QS2, LVET and PEP) and AFT (RRIV and QT/QS2) were measured in both the groups at the beginning and again at the end of three months study period.

It was found that the pranayam training produced an increase in RRIV and a decrease in QT/QS2 suggesting an enhanced parasympathetic and blunted sympathetic activity respectively. QS2, PEP and PEP/LVET increased significantly, whereas LVET was reduced significantly in pranayama group. In contrast, the changes in STI and AFT were much less marked in the control group. Their study showed that three months of pranayama training modulates ventricular performance by increasing parasympathetic activity and decreasing sympathetic activity.

A study was done by Desiraju et al. (1991) on oxygen consumption during pranayamic type of very slow-rate breathing. To determine whether the yogic ujjayi pranayamic type of breathing that involves sensory awareness and consciously controlled, extremely slow-rate breathing including at least a period of end-inspiration breath holding in each respiratory cycle would alter oxygen consumption or not, ten males with long standing experience in pranayama, and volunteering to participate in the laboratory study were assessed. These subjects aged 28-59 year, had normal health

appropriate to their age. Since kumbhak (timed breath holding) is considered as an important phase of the respiratory cycle in the pranayama, they were categorised into two groups of five each, one group practising the short kumbhak varieties of pranayama, and the other the long kumbhak varieties of pranayama. The duration of kumbhak phase was on an average 22.2 percent of the respiratory cycle in the short kumbhak group, and 50.4 percent in the long kumbhak group. The oxygen consumption was measured in test sessions using the closed circuit method of breathing oxygen through the Benedict-Roth spirometer. Each subject was tested in several repeat sessions. Values of oxygen consumption of the period of pranayamic breathing and of post-pranayamic breathing period were compared to control value of oxygen consumption of the prepranayamic breathing period of each test session.

The results revealed that the short kumbhak pranayamic breathing caused a statistically significant increase (52%) in the oxygen consumption (and metabolic rate) compared to the pre-pranayamic base-line period of breathing.

In contrast to the above, the long kumbhak pranayamic breathing caused a statistically significant lowering (19%) of the oxygen consumption (and metabolic rate).

A study was done by Murthy et al. (1994)

37 on comparison of effects of yoga and physical exercise in athletes. The effect of pranayama a controlled breathing practice, on exercise tests was studied in athletes in two phases; sub-maximal and maximal exercise tests. At the end of phase I (one year) both the groups (control and experimental) achieved significantly higher work rate and reduction in oxygen consumption per unit work.

It was found that there was a significant reduction in blood lactate and an increase in P/L ratio in the experimental group, at rest. At the end of phase II (two years), the oxygen consumption per unit work was found to be significantly reduced and the work rate significantly increased in the experimental group. Blood lactate decreased significantly at rest in the experimental group only. Pyruvate and pyruvate-

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lactate ratio increased significantly in both the groups after exercise and at rest in the experimental group.

The results in both phases showed that the subjects who practised pranayama could achieve higher work rates with reduced oxygen consumption per unit work and without increase in blood lactate levels. The blood lactate levels were significantly low at rest.

A study was done by Berrettini et al. (1978)\textsuperscript{38} on arterial blood gases in pranayama practice. Pranayama is a yogic breathing practice which is known experientially to produce a profound calming effect on the mind. In an experiment designed to determine whether the mental effects of this practice were accompanied by changes in the arterial blood gases, arterial blood was drawn from ten trained individuals prior to and immediately after pranayama practice.

It was found that no significance changes in arterial blood gases were noted after pranayama. A neural mechanism for the mental effects of this practice is proposed.

Rai, Balavittal, Thombre and Gitananda (1983)\textsuperscript{39} had done a study on cardiorespiratory change during savitri pranayama and shavasan. The study was conducted on trained (n=7) and untrained (n=7) volunteers to determine the effect of savitri pranayam and shavasan on O$_2$ consumption, heart rate and blood pressure. In trained subjects, it was found that a consistent and significant (p<0.01) reduction in O$_2$ consumption within a few minutes of starting savitri pranayama. During shavasan, there was significant reduction in O$_2$ consumption (p<0.05), heart rate (p<0.001) and diastolic blood pressure (p<0.05). In untrained subjects, the changes in above mentioned parameters were statistically insignificant.

A study was done by Joshi, Joshi, and Gokhale (1992)\textsuperscript{40} on effect of short term pranayama practice on breathing rate and ventilatory functions of lung. Thirty three


normal male and forty two normal female subjects, of average age of 18.5 years, underwent six weeks course in “pranayama” and their ventilatory lung functions were studied before and after this practice.

It was found that they had improved ventilatory functions in the form of lowered respiratory rate (RR), and increases in the forced vital capacity (FVC), forced expiratory volume at the end of 1st second (FEV1%), maximum voluntary ventilation (MVV), peak expiratory flow rate (PEFR-lit/sec) and prolongation of breathholding time.

It was found that the right, left and alternate nostril breathing groups had a significant increase in grip strength of both hands, ranging from 4.1% to 6.5%, at the end of the camp though without any lateralization effect. The breath awareness and mudra groups showed no change.

Hence it was concluded that yoga breathing through a particular nostril or through alternate nostrils increases hand grip strength of both hands without lateralization.

Dash and Telles (1998)\textsuperscript{41} used a finger tapping task to assess motor speed (MS) of both hands in 53 adults and 152 children before and after yoga training and in 38 adults of a non-yoga (control) group. All subjects were right hands dominant. The 30 second tapping speed (TS) test was considered as three time intervals, i.e. 0-10 second (TS1), 10-20 seconds (TS2) and 20-30 seconds (TS3). There was a significant (student’s t-test) increase in all three TS values following 10 days of yoga in children and 30 days of yoga in adults. However for both groups at baseline and final assessments, TS2 and TS3 were significantly lower than TS1. Hence, the TS were increased after yoga training during the first 10-seconds of the test but not during the next 20 seconds. These results suggest an increase in motor speed for repetitive finger movements following yoga training, but not in strength or endurance, as the increase was not sustained over 30 seconds.

A study by Madanmohan et al. (2004)\textsuperscript{42} reports the effects of yoga training on cardiovascular response to exercise and the time course of recovery after the exercise.


Cardiovascular response to exercise was determined by harvard step test using a platform of 45 cm height. The subjects were asked to step up and down the platform at a rate of 30/minute for a total duration of five minutes or until fatigue, whichever was earlier. Heart rate (HR) and blood pressure response to exercise were measured in supine position before exercise and at one, two, three, four, five, seven and ten minutes after the exercise. Rate pressure product \[RPP = (HR \times SP) / 100\] and double product \[(Do \ P = HR \times MP)\], which are indices of work done by the heart rate also calculated. Exercise produced a significant increase in HR, systolic pressure, RPP and Do P and a significant decrease in diastolic pressure. After two months of yoga training, exercise-induced changes in these parameters were significantly reduced. It was concluded that after yoga training a given level of exercise leads to a milder cardiovascular response, suggesting better exercise tolerance.

Although there are a number of reports on the effect of yoga training on pulmonary functions, very few studies have been undertaken on the effect of yoga training on respiratory pressures and hand grip endurance. Hence Madnamohan et al. (2003)\(^{43}\) planned to study the effect of yoga training on handgrip strength (HGS), handgrip endurance (HE), maximum inspiratory pressure (MIP), forced expiratory volume (FEV), forced expiratory volume in first minute (FEV\(_1\)) and peak expiratory flow rate (PEFR). 20 school children in the age group of 12 to 15 years were given yoga training (asanas and pranayamas) for six months. 20 age and gender matched students formed the control group. Yoga training produced statistically significant (P<0.05) increase in HGS and HE. MEP, MIP, FEV\(_1\) and PEFR also increase significantly (P<0.001) after the yoga training. In contrast, the increase in these parameters in the control group was statistically insignificantly insignificant. Their study showed that yoga training for six months improves lung functions, strength of inspiratory and expiratory muscles as well as skeletal muscle strength and endurance. It was suggested that yoga be introduced at school level in order to improve physiological functions, overall health and performance of students.

During recent years, a lot of research work has been done to show the beneficial effects of yoga training. Yadav and Das (2001) undertook the study to assess the effects of yogic practice on some pulmonary functions. Sixty healthy young female subjects (age group 17-28 years) were selected. They had to do the yogic practices daily for about one hour. The observations were recorded by MEDSPIROR, in the form of FVC, FEV-1 and PEFR on day one, after six weeks and twelve weeks of their yogic practice. There was significant increase in FVC, FEV-1 and PEFR at the end of 12 weeks.

Asthma is one of the common psychosomatic illnesses influenced by many factors. Bronchodilators give temporary relief and have side effects. Sathyaprabha, Murthy and Murthy (2001) conducted the study aiming at finding the efficacy of a non-pharmacological approach of naturopathy and yoga in bronchial asthma. A total number of 37 patients (19 men and 18 women) with mean age 35.06 years (men), 40.74 years (women) admitted to INYS, Bangalore, for the period of 21 days.

The treatment included (1) diet therapy (2) nature cure treatment and (3) yoga therapy. The various parameters including lung function test were measured on admission and once a week. Results showed the significant improvement in PEFR, VC, FVC, FEV1, FEC%, MVV, ESR and absolute eosinophil count. The patients reported a feeling of well being, freshness and comfortable breathing. Naturopathy and yoga helps in inducing positive health, alleviating the symptoms of disease by acting at physical and mental levels.

The effect of yogic training on cardiac recovery index (CRI) was studied by Muralidhara and Ranganathan (1982) in ten healthy male medical students and in ten matched controls. Statistically significant increase in CRI as assessed by harvard step test was observed in yoga trained subjects after two and half months of training.

Effect of inspiratory and expiratory phases of normal quiet breathing, deep breathing and savitri pranayam type breathing on heart rate and mean ventricular QRS was investigated by Madanmohan et al. (1986)\(^{47}\) in young healthy untrained subjects. Pranayama type breathing produced significant cardio acceleration and increase in QRS axis during the inspiratory phase as compared to eupnoea. On the other hand, expiratory effect during pranayama type breathing did not produce any significant change in heart rate or QRS axis. The changes in heart rate and QRS axis during the inspiratory and expiratory phases of pranayama type breathing were similar to the changes observed during the corresponding phases of deep breathing.

According to Singh, Tamburinath and Karve (2009)\(^{48}\), Kop Maor’s technique of slow chanting and breathing exercise (inhaling and exhaling) and De Silva’s visual imaging technique are expected as moderator of performance in sports. Breathing techniques would help to have complete control over the autonomic nervous system which is proved to be central aspect and central concern for attaining success in any kind of individual and team games. And on the other hand long back American world famous psychologist Kop Mayor proved that slow chanting makes neurological system completely prepared to attain a set goal. In the same line De Silva’s also long back proved that visual imaging would make right hemisphere stronger that is base for attaining desired success.

Hypertension is one of the mortal diseases in modern human life. Psychological factors have many important roles in creation of hypertension. “Stress” can account for 10% of blood pressure variance. A variety of psychotherapeutic interventions, such as relaxation techniques or yoga training, can lower hypertension.

There is evidence that that the practice of yoga improve physical and mental performance. Madanmohan et al.(1992)\(^{49}\) undertook the study to investigate the effect of

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yoga training on visual and auditory reaction times (RTs), maximum expiratory pressure (MEP), maximum inspiratory pressure (MIP), 40 mmHg test, breath holding time after expiration (BHTexp), breath holding time after inspiration (BHT insp) and hand grip strength (HGS). Twenty seven volunteers were given yoga training for twelve weeks. There was a significant (P<0.001) decrease in visual RT (from 270.0±6.20 (SE) to 224.81±5.76 ms) as well as auditory RT (from 194.18±6.00 to 157.33±4.85ms), MEP increase from 92.61± 9.04 to136.46±10.75 mmHg, while MIP increase from 72.23±6.45 to 90.92±6.03 mmHg, both these changes being statistically significant (P<0.05), 40 mmHg test and HGS increased significantly (P<0.001) from 36.57±2.04 to 53.36±3.95 s and 13.78 ±0.58 to 16.67±0.49 kg respectively. BHTexp increased from 32.15±1.41 to 44.53±3.78 s (P<0.01) and BHTinsp increase from 63.69±5.38 to 89.07±9.61 s (P<0.05) and BHTinsp increased from 63.69±5.38 to 89.07±9.61 s (P<0.05). Their results showed that yoga practice for twelve weeks results in significant reduction in visual and auditory RTs and significant increase in respiratory pressures, breath holding times and HGS.

2.7. Effect of Breathing Exercises and Pranayamas on Psychological Variables

A study was done by Block, Arnott, Quigley and Lynch (1989)50 on unilateral nostril breathing influences lateralized cognitive performance. Relative nostril efficiency (nasal cycle) is related to hemispheric EEG differences and performance on cognitive tasks. They investigated how unilateral forced nostril breathing influences spatial and verbal performance. Right-handed males and females performed both tasks under either left-nostril, right-nostril or free-breathing conditions. Unilateral breathing affects performance differently in males and females. It influences male performance laterally on both tasks: Their spatial performance is better during right-nostril breathing, and their verbal performance is better during left nostril breathing. Unilateral breathing influences female performance contra laterally, but only on the spatial task: Their spatial performance is better during left-nostril breathing. These differences within and between sexes may exist because unilateral nostril breathing differentially activates the

two hemispheres and thereby facilitates performance, or because attempts of the brain to control the nasal cycle unilaterally interfere with performance.

A study was done by Joshi and Telles (2008)\textsuperscript{51} on immediate effects of right and left nostril breathing on verbal and spatial scores. The immediate effect of two yoga breathing techniques was assessed on verbal and spatial memory tasks, considered hemisphere-specific. Forty-five participants (24 males; age range 20 to 45 years (mean age 27.1 +/- 8.1 years) were randomly allocated to three groups (n = 15 each) and were assessed immediately before and after 45 minutes of three breathing practices i.e., right nostril yoga breathing, left nostril yoga breathing, or breath awareness as a control intervention. Spatial memory scores increased after left nostril yoga breathing compared to before (by 16 percent, P = 0.03, paired t-test).

Hence, breathing through the left nostril increased performance in a spatial cognitive task, corresponding to the cerebral hemisphere contralateral to the patent nostril.

A study was done by Brown and Gerbarg (2005)\textsuperscript{52} on sudarshan kriya yogic breathing in the treatment of stress, anxiety and depression: part ii—clinical applications and guidelines. Yogic breathing is a unique method for balancing the autonomic nervous system and influencing psychologic and stress-related disorders. Part I of this series presented a neurophysiologic theory of the effects of sudarshan kriya yoga (SKY). Part II will reviewed clinical studies, their own clinical observations, and guidelines for the safe and effective use of yoga breathe techniques in a wide range of clinical conditions. Although more clinical studies are needed to document the benefits of programs that combine pranayama (yogic breathing) asanas (yoga postures) and meditation, there is sufficient evidence to consider sudarshan kriya yoga to be a beneficial, low-risk, low-cost adjunct to the treatment of stress, anxiety, post-traumatic stress disorder (PTSD), depression, stress-related medical illnesses, substance abuse and rehabilitation of criminal offenders. SKY has been used as a public health intervention to alleviate PTSD.


in survivors of mass disasters. Yoga techniques enhance well-being, mood, attention, mental focus and stress tolerance. Proper training by a skilled teacher and a 30-minute practice every day will maximize the benefits. Health care providers play a crucial role in encouraging patients to maintain their yoga practices.

A study was done by Balayogi, Madanmohan and Kaviraja Udupa (2003)\textsuperscript{53} on acute effect of mukh bhasrika (a yogic bellows type breathing) on reaction time. Reaction time (RT) is an index of the processing ability of the central nervous system and a simple means of determining sensory-motor performance. It has been reported that yoga training improves human performance including central neural processing. Earlier studies from their laboratories had shown that yoga training produces a significant decrease in visual reaction time (VRT) and auditory reaction time (ART). The present work was planned to determine if mukh bhasrika (a yogic technique in which breath is actively blasted out in “whooshes” following a deep inspiration) has any effect on central neural processing by studying its effect on RT. 22 healthy schoolboys who were practicing yoga for the past three months were recruited for the conducted study. VRT and ART were recorded before and after nine rounds of mukh bhasrika.

It was found that mukh bhasrika produced a significant (P<0.01) decrease in VRT as well as ART. A decrease in RT indicates an improved sensory-motor performance and enhanced processing ability of central nervous system. This may be due to greater arousal, faster rate of information processing, improved concentration and/or an ability to ignore extraneous stimuli. This is of applied value in situations requiring faster reactivity such as sports, machine operation, race driving and specialized surgery. It may also be of value to train mentally retarded children and older sports persons who have prolonged RT.

A study was done by Joseph et.al. (1992)\textsuperscript{54} on alteration of auditory middle latency evoked potentials during yogic consciously regulated breathing and attentive

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state of mind. Middle latency auditory-evoked potentials (AEP-MLRs) of 10 healthy male subjects in the age range of 21-33 years, were assessed to determine whether yogic pranayamic practice would cause changes in them. The pranayama type assessed there is an exercise of consciously-controlled rhythmic breathing involving timed breath-holding in each cycle of breathing, while the subject holds utmost attention and experiences the touch of inhaled air in the nasal passage.

The results revealed that the Na-wave amplitude increased and latency decreased during the period of pranayamic practice, whereas the Pa-wave was not significantly altered. The change is interpreted as an indication of a generalized alteration cause in information processing at the primary thalamo-cortical level during the concentrated mental exercise of inducing modifications in neural mechanisms regulating a different functional system (respiratory).

A study was done by Khalsa et al. (1991) on the effects of unilateral forced nostril breathing on cognition. Ultradian rhythms of alternating cerebral dominance have been demonstrated in humans and other mammals during waking and sleep. Human studies have used the methods of psychological testing and electroencephalography (EEG) as measurements to identify the phase of this natural endogenous rhythm. The periodicity of this rhythm approximates 1.5 – 3 hours in awake humans. This cerebral rhythm is tightly coupled to another ultradian rhythm known as the nasal cycle, which is regulated by the autonomic nervous system and is exhibited by greater airflow in one nostril, later switching to the other side. This paper correlates uninostril airflow with varying ratios of verbal/spatial performance in 23 right-handed males. Relatively greater cognitive ability in one hemisphere corresponds to unilateral forced nostril breathing in the contralateral nostril. Cognitive performance ratios can be influenced by forcibly altering the breathing pattern.

A study was done by Shirley et al. (1997) on yoga breathing through a particular nostril increases spatial memory scores without lateralized effects. Uninostril

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breathing facilitates the performance on spatial and verbal cognitive tasks, said to be right and left brain functions, respectively. Since hemispheric memory functions are also known to be lateralized, the conducted study assessed the effects of uninostril breathing on the performance in verbal and spatial memory tests. School children (N = 108 whose ages ranged from 10 to 17 years) were randomly assigned to four groups. Each group practiced a specific yoga breathing technique: (i) right nostril breathing, (ii) left nostril breathing, (iii) alternate nostril breathing, or (iv) breath awareness without manipulation of nostrils. These techniques were practiced for ten days. Verbal and spatial memory was assessed initially and after ten days. An age-matched control group of 27 were similarly assessed. It was found that all four trained groups showed a significant increase in spatial test scores at retest, but the control group showed no change. Average increase in spatial memory scores for the trained groups was 84%. It was appeared that yoga breathing increases spatial rather than verbal scores, without a lateralized effect.

Rajora and Prajapati (2009) examined the effect of selected on emotional intelligence and intelligence quotient of school going children. The samples were 40 students of the Anandalay higher secondary section. Before the practice of the selected yogic exercises their EM with emotional intelligence test by N.K. Chadha and the IQ with IQ test for school children constructed by Desai for the students of Gujarat. Then they were divided into two groups by random sampling method. The experimental group practiced the yogic exercises- asanas and pranayam. The practice lasted for four weeks. The mean of score, standard deviation of the two groups were analyzed by t-test at both level of significance (0.05 and 0.01). For the EI t- test result was 5.28 which were significant and for the IQ it was 10.2 which were insignificant. The study revealed that four week yogic exercises on experimental group did result insignificant difference in the EI. But they showed the insignificant difference in the IQ level of the students.

A study was done by Jella and Shannahoff-Khalsa (1992) on the effects of unilateral forced nostril breathing on cognitive performance. This study describes the

effects of 30 minutes of unilateral forced nostril breathing on cognitive performance in 51 right-handed undergraduate psychology students (25 males and 26 females). A verbal analogies task modeled after the Miller analogies and SAT tests was used as a test of left-hemispheric performance and mental rotation tasks based on the Vandenburg and Kuse adaptation of Shepard and Metzler’s tests were used as spatial tasks for testing right-hemispheric performance.

It was found that spatial task performance was significantly enhanced during left nostril breathing in males and females, $p = .028$. Verbal task performance was greater during right nostril breathing, but not significantly $p = .14$. These results are discussed in comparison to other cognitive and physiological studies using unilateral forced nostril breathing.

It was concluded that this yogic breathing technique may have useful application in treating psychophysiological disorders with hemispheric imbalances and disorders with autonomic abnormalities.

2.8. Effect of Specific Postural Asanas on Autonomic Functions

A study was done by Ram et al. (1993)\textsuperscript{59} on energy expenditure and ventilatory responses during virasana—a yogic standing posture. Energy expenditure and ventilatory responses to yogic standing posture of virasana were studied on ten healthy men (25-37 years of age). The results of various responses respectively to the horizontal supine, chair-sitting and virasana were: minute ventilation (VE) 7.64, 8.61 and 18.67 L/minutes; respiratory frequency (FR) 15.71, 15.70 and 21.45 breath/minutes; tidal volume (VT) 0.496, 0.544 and 0.827 L/minutes; Oxygen consumption (VO2) 0.127, 0.234 and 0.573 L/minutes; Carbon dioxide Elimination (VCO2) 0.127, 0.134 and 0.420 L/min; respiratory exchange ratio (RER) 0.58, 0.57 and 0.69; heart frequency (FH) 65.2, 74.5 and 104.4 beats/minutes; oxygen pulse (O2P) 3.32, 3.17 and 5.45 ml/beat; ventilatory equivalent (VE-EQ) 36.78, 37.12 and 33.85; multiple of resting VO2 (METS) 0.96, 1.05 and 2.53 and metabolic cost (MC) 1.04, 1.13 and 2.76 Cal/minutes. Virasana posture was characterised by higher VE, FR, VT, VO2, VCO2, FH and O2P with lesser VE-EQ.

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The observations suggest that virasana induces temporarily a hypermetabolic state characterised by enhanced sympathetic nervous system activity which gets inhibited during the adoption of resting supine shavasana posture.

Telles (2003) \(^{60}\) had done a study on effects of sirsasana (headstand) practice on autonomic and respiratory variables. The conducted study had two aims: (1) to assess heart rate variability (HRV) along with non-specific autonomic measures (used in earlier studies), before and after two minutes of the headstand (2) to compare changes in two categories of subjects, i.e., those who practiced the headstand in a traditional way (without any support) and those who used the support of the wall (a present day adaptation). The subjects were forty male volunteers (age range 19 to 36 years), with twenty subjects under each category.

It was found that the following changes were significant after the practice, compared to values at baseline. (i) Both categories had an increase in the power of the low frequency component (LF) and a decrease in the high frequency component (HF) of the HRV spectrum, increased LF/HF ratio and decreased heart rate. (ii) Subjects who practiced the headstand with the support of a wall showed reduced finger plethysmogram amplitude suggesting increased sympathetic vasomotor tone. (iii) Practicing the headstand without support was associated with an increase in the skin conductance level, suggestive of increased sympathetic sudomotor tone. Hence, it was concluded that both categories showed similar changes in the HRV components though changes in sympathetic vasomotor and sudomotor activity were different. These changes suggest sympathetic activation, irrespective of the method of practice.

2.9. Effect of General Yogic Exercises on Autonomic Nervous System

A study was done by Nayar et al. (1983) \(^{61}\) on physiological effects of yogic practices. This comprehensive study was conducted on 30 healthy men [soldiers] (20-30 years of age) to evaluate the effects of six months of regular yogic practice on


autonomic balance, thermoregulatory efficiency, orthostatic tolerance, energy metabolism and biochemical profile. The subjects were randomly divided into two groups (A and B) of 15 each. Group-A served as control, while in group-B yogic training was administered daily in the morning hours for one hour under the supervision of qualified yoga instructor from Vishwaytan Yogashram for six months. Various physiological tests and biochemical estimations were done before and after, every month of yogic training, in both the groups.

Yogic practice for six months resulted in a trend of shift in the autonomic equilibrium towards relative parasympathodominance, improvement in thermoregulatory efficiency and orthostatic tolerance. It has also brought about improvement in physical performance by minimizing the energy expenditure during submaximal exercise. The changes in the biochemical profile indicated a relative hypometabolic state after six months of yogic practice.

A study was done by Sathyaprabha, Satishchandra et al.(2008) on modulation of cardiac autonomic balance with adjuvant yoga therapy in patients with refractory epilepsy. The practice of yoga regulates body physiology through control of posture, breathing, and meditation. Effects of yoga on autonomic functions of patients with refractory epilepsy, as quantified by standardized autonomic function tests (AFTs), were determined. The yoga group (n = 18) received supervised training in yoga and the exercise group (n = 16) practiced simple routine exercises. AFTs were repeated after ten weeks of daily sessions. Data were compared with those of healthy volunteers (n = 142).

The yoga group showed significant improvement in parasympathetic parameters and a decrease in seizure frequency scores. There was no improvement in blood pressure parameters in either group. Two patients in the yoga group achieved normal autonomic functions at the end of ten weeks of therapy, whereas there were no changes in the exercise group.

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The data suggest that yoga may have a role as an adjuvant therapy in the management of autonomic dysfunction in patients with refractory epilepsy.

A study done by Vempatti and Telles (2002) on yoga-based guided relaxation reduces sympathetic activity judged from baseline levels. 35 male volunteers whose ages ranged from 20 to 46 years were studied in two sessions of yoga-based guided relaxation and supine rest. Assessments of autonomic variables were made for 15 subjects, before, during and after the practices, whereas oxygen consumption and breath volume were recorded for 25 subjects before and after both types of relaxation.

A significant decrease in oxygen consumption and increase in breath volume were recorded after guided relaxation (paired t test). There were comparable reductions in heart rate and skin conductance during both types of relaxation. During guided relaxation the power of the low frequency component of the heart-rate variability spectrum reduced, whereas the power of the high frequency component increased, suggesting reduced sympathetic activity. Also, subjects with a baseline ratio of LF/HF > 0.5 showed a significant decrease in the ratio after guided relaxation, while subjects with a ratio < or = 0.5 at baseline showed no such change.

Hence it was concluded that sympathetic activity decreased after guided relaxation based on yoga, depending on the baseline levels.

2.10. Clinical Studies on Autonomic Nervous System and Heart Rate Variability

Bhavanani and Udupa (2002) did a study on effect of direction of head on heart rate and blood pressure. Indian culture stresses the importance of direction during performance of daily activities. Some yoga teachers prescribe that yogic relaxation and polarity practices must be done while lying with head towards north in order to align oneself with the earth’s electromagnetic field. There is some evidence that earth’s magnetic field influences physiological functions. Hence, the conducted study was

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undertaken to see whether head direction has any effect on heart rate (HR) and blood pressure during supine rest. 43 normal healthy school children were recruited and their recordings were taken after five minutes of supine rest. The subjects were randomly assigned to lie with their head towards north, east, south and west directions on four different days. HR and blood pressure were recorded at the end of five minutes of supine rest.

It was found that HR was lowest in north and highest in south, the difference being statistically significant by students’ paired “t” test. Systolic pressure was lowest in the north and significantly higher in the west. Lying supine with head towards north had the lowest rate-pressure-product as compared to the west. Study demonstrates that lying supine with head in different directions has a definite effect on the HR and blood pressure.

A study was done by Cysarz, Dirk, Bonin, Lackner, Heusser, Moser and Bettermann (2004) on oscillations of heart rate and respiration synchronize during poetry recitation. The objective of the study was to investigate the synchronization between low frequency breathing patterns and respiratory sinus arrhythmia (RSA) of heart rate during guided recitation of poetry, i.e., recitation of hexameter verse from ancient Greek literature performed in a therapeutic setting. Twenty healthy volunteers performed three different types of exercises with respect to a cross-sectional comparison: 1) recitation of hexameter verse, 2) controlled breathing and 3) spontaneous breathing. Each exercise was divided into three successive measurements: a 15 minutes baseline measurement (S1), 20 minutes of exercise and a 15 minutes effect measurement (S2). Breathing patterns and RSA were derived from respiratory traces and electrocardiograms, respectively, which were recorded simultaneously using an ambulatory device. The synchronization was then quantified by the index, which has been adopted from the analysis of weakly coupled chaotic oscillators. During recitation of hexameter verse, was high, indicating prominent cardiorespiratory synchronization.

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It was found that the controlled breathing exercise showed cardiorespiratory synchronization to a lesser extent and all resting periods (S1 and S2) had even less cardiorespiratory synchronization. During spontaneous breathing, cardiorespiratory synchronization was minimal and hardly observable. The results were largely determined by the extent of a low-frequency component in the breathing oscillations that emerged from the design of hexameter recitation.

Hence it was concluded, recitation of hexameter verse exerts a strong influence on RSA by a prominent low frequency component in the breathing pattern, generating a strong cardiorespiratory synchronization.

Psychological stress is a risk factor for hypertension and coronary artery disease. Srinivasan, Vaz and Sucharita (2006) conducted the study to assess the impact of real life stressor, that of stress among first year medical students on cardiac autonomic regulation. Stress levels in 36 non-smoking, healthy first year medical students of either gender were assessed on a self-rating scale. Cardiac autonomic regulation was tested using both conventional tests and spectral analysis of heart rate variability (HRV). Nine subjects who obtained scores on the stress scale in the upper quartile were classified as the “stress” group and the rest constituted the “no stress” group (n=27). There were no significant differences between the two groups on any of the conventional tests of autonomic nervous activity. The low frequency power in normalized units and low frequency high frequency ratio of heart rate variability in supine posture was significantly higher in the “stress” group compared to the “no stress” group. The low frequency power in normalized units was significantly positively correlated with total stress score. The changes were suggestive of a tilt in the resting cardiac autonomic balance towards increased sympathetic activity.

Mc Craty et al. (1993) on subtle energies and energy. This work utilizes the measurement of heart rate variability (HRV) as a vehicle to show that continued practice of certain specific techniques involving an intentional shift of focus to the area

of the heart, and invoking specific feeling states such as “love” and “appreciation,” automatically manifests in increased autonomic nervous system balance. In particular, (1) enhanced balance between the parasympathetic and sympathetic nervous system, (2) a shift of the high frequency and low frequency portions of the HRV power spectra to around 0.1 Hz range, (3) entrainment and frequency portions of the HRV power spectra to around 0.1 Hz frequency, associated with a change in focus of the subject to a different heart feeling state and (5) the intentional generation of a newly defined internal coherence state (near zero HRV) have all been achieved. These are electrophysiological correlates of certain mental and emotional states occupied by the individual. Three individual subjects plus a group study of twenty subjects were reported on and discussed. From the results, one sees that individuals can intentionally affect their autonomic nervous system balance, and thus, their HRV.

The purpose of the conducted study by Madanmohan, Prakash and Bhavanani (2005) was to determine whether readily measured blood pressure (BP) indices and responses to autonomic reflex tests could be used as surrogates of short term heart rate variability (HRV), which is an established marker of autonomic regulation of SA node. Therefore, they examined the correlation between short term HRV and heart rate (HR), BP indices viz. systolic pressure, diastolic pressure, pulse pressure (PP) and rate-pressure product (RPP), during supine rest and head-up tilt in 17 young healthy normotensive subjects, aged 19.8±1 year (mean± SD). Three classic autonomic indices viz. valsalva ratio, HR response to deep breathing and pressure response to isometric handgrip were also determined. They noted two interesting and statistically significant (P<0.05 in both cases) correlations viz. (i) a positive correlation (r=0.6) between change in RPP during tilt and change in low frequency (LF) RR spectral power expressed in normalized units (LF nu) during tilt and (ii) a negative correlation (r=-0.6) between change in PP during isometric handgrip and LF nu during tilt. In conclusion, the presence of a statistically significantly correlation between RPP, PP and spectral measures of short-term HRV supports a simplistic approach to as surrogates of HRV

when it is not feasible to determine HRV indices directly. However, the same have to be tested in healthy subjects belonging to various age groups and in patients with conditions known to be associated with autonomic dysregulation.

2.11. Comparison Between Yogic Exercises and Physical Activities

Shome and Bannerjee (2009) made an attempt to observe the improvement occurring in the psychological variables following aerobic and yoga practices among the adolescents. The purpose of the study was to evaluate acute psychological (intelligence, interest, memory and reaction time) responses to hatha yoga asana (poses), aerobic dance and combined (hatha yoga and aerobic dance). 120 subjects (12-16 yrs) were recruited and randomized to four groups. Experimental subjects completed a six week supervised exercise program. Control subjects continued usual activity. Three experimental groups were practiced thrice a week and 30 minutes per day. Intelligence was measured by the Mill Hill vocabulary scale; progressive matrices (1938) were constructed. Interest was measured by the Nelson hand reaction Test (1965). For testing the difference between means of selected psychological variables of hatha yoga group, aerobic dance group, combined group (hatha yoga and aerobic dance) and control group of girls. ANOVA and ANKOV A method was applied. The level of significance was set as 0.05 and 0.01 level of confidence. It was supervised that hatha yoga, aerobic dance, combined groups increased intelligence, interest, memory and reaction time but it showed that combined group (yoga and aerobic) is better than all the other groups.

Thakur and Babdopadhyay (2009) compared yoga asanas and gymnastic activities on self-concept and attitude among school going boys. One hundred fifty (150) male school children of District Howrah, West Bengal State were randomly selected as subjects for the conducted study. The age limit of the subjects was 10-12 years. All the subjects were divided into three equal groups such as Y, G and C.


Y (yoga asanas group) and group G (gymnastic group) were experimental groups and group C was control group.

Initially Dr. Beena Shah’s Self concept Inventory scale and Rao’s School Inventory Scale were employed to all the subjects of each group and thereafter specific yogic activities were given to group Y and G respectively for four day in week and continued one year and finally the subjects were retested on criterion measures. The data were analyzed by t- ratio to find out the effects of the treatment and level of significance was set at 0.05 level of confidence. The result of the study showed that yoga asanas group was superior to gymnastics group and control group and gymnastic group was also superior to control group.

Buffalo health study concluded that pulmonary function is a long-term predictor for overall survival rates. It is essential to be involved in physical activity or sports which help in achieving better lung function. Cross sectional observation study was conducted by Prakash, Meshram and Ramtekkar (2007) to determine if yoga and athletic activity (running) are associated with better lung functions as compared to subjects with sedentary lifestyles and how athletes and yogis differ in lung function. Spirometric parameters were assessed in randomly selected 60 healthy male, non-smoking, non-obese subjects- athletes, yogis and sedentary workers. The highest mean FEV\textsubscript{1} and PEFR were observed in yogis. Both yogis and athlete had significantly better FEV\textsubscript{1} as compared to sedentary workers. Yogis also had significantly better PEFR as compared to sedentary workers and athletes. Yogis and athletes had similar lung functions except for better PEFR amongst yogis. Involvement in daily physical activity or sport preferably yoga can help in achieving better pulmonary function.

2.12. Effect of Physical Exercise/Training on the Functions of Autonomic Nervous System

Aerobic exercise leads to reduced sympathetic and increased cardiac vagal modulation, providing an antiarrhythmic effect. The optimal exercise intensity to

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promote this adaptation remains undefined. The aims of L Soares-Miranda et al. (2000)\textsuperscript{72} for the conducted investigation were two fold, first to examine differences in heart rate variability (HRV) measures in participants with different levels of objectively measured physical activity (PA) and second, to identify the characteristic of PA which most influences the cardiac autonomic nervous system (cANS) function in young adults. Cross-sectional evaluation of 84 adults examining relationships between PA amount and intensities, measured by accelerometry, cANS function derived from HRV. Groups were created based on tertiles of PA and analysis of covariance was used to assess between-group differences in HRV. Stepwise regression analysis was used to determine the characteristic of PA, which best predicted vagal HRV indices. There were significantly higher levels of vagal HRV indices in the most active group compared with the least active group. Regression analysis revealed that the number of bouts of vigorous PA undertaken was the best predictor of the vagal HRV indices assessed. The study suggests that vagal modulation is enhanced with high levels of PA and that it is the number of bouts of vigorous PA that is most closely associated with cANS function.

The 30 to 15 intermittent fitness test (30 to 15IFT) is an attractive alternative to classic continuous incremental field tests for defining a reference velocity for interval training prescription in team sport athletes. M Buchheit, H Al Haddad, GP Millet, PM Lepretre, M Newton and S Ahmaidi (2009)\textsuperscript{73} done a study on cardio respiratory and cardiac autonomic responses to 30-15 intermittent fitness test in team sport players. The aim of the conducted study was to compare cardiorespiratory and autonomic responses to 30 to 15IFT with those observed during a standard continuous test (CT). In 20 team sport players 20.9 ± 2.2 years), cardiopulmonary parameters were measured during exercise and for 10 minutes after both tests. Final running velocity, peak lactate ([La] peak) and rating of perceived exertion (RPE) were also measured. Parasympathetic function was assessed during the post exercise recovery phase via heart rate (HR) recovery time constant (HRR [\(\tau\)]) and HR variability (HRV) vagal-related indices. At

\textsuperscript{73} M Buchheit, H Al Haddad, GP Millet, PM Lepretre, M Newton and S Ahmaidi, “Cardio Respiratory and Cardiac Autonomic Responses to 30-15 Intermittent Fitness Test In Team Sport Players”, \textit{J Strength Cond Res.}, Jan 2009,23(1): 93-100.
exhaustion, no difference was observer in peak oxygen uptake VO$_{2peak}$, respiratory exchange ratio, HR, or RPE between 30-15 IFT and CT. In contrast, 30 to 15 IFT led to significantly higher minute ventilation, [La] peak, and final velocity than CT (p < 0.05 for all parameters). All maximal cardio respiratory variables observed during both tests were moderately to well correlated (e.g., r = 0.76, p = 0.001 for Latin capital VO$_{2peak}$). Regarding ventilatory thresholds (VThs), all cardio respiratory measurements were similar and well correlated between the two tests. Parasympathetic function was lower after 30-15IFT than after CT, as indicated by significantly longer HHR [tau] (81.9 ± 18.2 vs. 60.5 ± 19.5 for 30 to 15IFT and CT, respectively, p < 0.001) and lower HRV vagal-related indices (i.e., the root mean square of successive R-R intervals differences [RMSSD]: 4.1 ± 2.4 AND 7.0 ± 4.9 milliseconds, p < 0.05). In conclusion, the 30 to 15 IFT is accurate for assessing VThs and VO$_{2peak}$, but it alters post exercise parasympathetic function more than a continuous incremental protocol.

M Buchheit, JJ Peiffer, CR Abbiss and PB Laursen, (2009) conducted a study on ‘effect of cold water immersion on post exercise parasympathetic reactivation’ The aim of the study was to assess the effect of cold water immersion (CWI) on post exercise parasympathetic reactivation. Ten male cyclists (age, 29 ± 6 years) performed two repeated supramaximal cycling exercises [SE (1)and SE(2)] interspersed with a 20 minute passive recovery period, during which they were randomly assigned to either five minute of CWI in 14°C or a control (N) condition where they sat in an environmental chamber (35.0 ± 0.3°C and 40.0 ± 3.0% relative humidity). Rectal temperature [T (re)] and beat-to-beat heart rate (HR) were recorded continuously. The time constant of HR recovery (HRR$_{tau}$) and a time (30 second) varying vagal-related HR variability (HRV) index [RMSSD (30 second)] were assessed during the six minute period immediately following exercise. Resting vagal-related HRV indexes were calculated during three minute period two minute before and three minute after SE (1) and SE (2). Results showed no effect of CWI on T (re) (p = 0.29), SE performance (p = 0.76) and HRRtau (p = 0.61). In contrast, all vagal-related HRV indexes were decreased after SE (1) (p < 0.001) and tended to decrease even further after SE (2) under N

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condition but not with CWI. When compared with the N condition, CWI increased HRV indexes before (p < 0.05) and RMSSD (30 second) after (P < 0.05) SE (2). Study showed that CWI can significantly restore the impaired vagal-related HRV indexes observed after supramaximal exercise. CWI may serve as a simple and effective means to accelerate parasympathetic reactivation during the immediate period following supramaximal exercise.

D Ataoui, V Pichot, L Lacoste, F Barale, JR Lacour and JC Chatard (2007) done a study on ‘heart rate variability, training variation and performance in elite swimmers’ The aim of the conducted study was to investigate the relationships between heart rate variability (HRV) changes and both training variations and performances in elite swimmers. A secondary purpose was to measure catecholamine urinary excretion in elite swimmers to validate the HRV indices of sympathetic activity during training. Thirteen swimmers (four females and nine males) were tested before and after four weeks of intense training (IT) and three weeks of reduced training (RT). At the end of each period, the swimmers participated in an official competition of their best even. Individual performances were expressed as percentage of the previous season’s best performance. Spectral analysis was used to investigate RR interval variability. HRV indices failed to show any significant changes between the study periods (p > 0.05). Pre-IT HF was correlated with performance (r = 0.45; p = 0.05) and HFnu (r=0.59; p < 0.05) during RT. On the other hand, once RT was completed, HFnu was correlated positively to performance (r = 0.81; p < 0.01) and negatively to fatigue (r = - 0.63; p < 0.03). Conversely, the indices of sympathetic activity, i.e., LF nu and LF/HF ratio were inversely related to performance (both r = - 0.81; p < 0.01); total fatigue score was correlated to the changes in HF nu (r = - 0.63; p < 0.03) and in the LF/HF ratio (r = - 0.58; p < 0.05). Changes in the adrenaline / non adrenaline ratio over the follow-up period were related to the changes in the LF/HF ratio (r = - 0.45; p < 0.03). In highly trained swimmers coping well with a training program, including four weeks of IT followed by three weeks of RT, HRV indices were unaltered. On the other hand, after

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the three weeks of RT, HFnu was positively related to performance and inversely related to the fatigue score.

Thus, elevated initial HF levels could be important in the parasympathetic activity increases during taper and, hence, in swimming performance improvement.

A study was done by GR Sandercock, PD Beromley and DA Brodie (2005)\(^{76}\) on effects of exercise on heart rate variability: inferences from meta-analysis. Chronic exercise training produces a resting bradycardia that is thought to be due partly to enhanced vagal modulation. The aim of the study was to determine the effects of exercise training on heart rate and measures of heart rate variability associated with vagal cardiac modulation and to quantify the relationship between changes in these measures. A random effects model of effect size for change in high frequency (HF) power and RR interval was calculated. Within-group heterogeneity was assessed using the Q statistic. Where heterogeneous effects were found, subgroup analyses were performed using the between-group Q statistic. A meta-analysis of 13 studies measuring HF (N = 322 cases) produced an overall effect size of $d = 0.48$ (C.I. 0.26-0.70, $P = 0.00003$). Twelve studies (298 cases) reported a change in RR interval with an overall effect size of $d = 0.75$ (C.I. 0.51-0.96, $p < 0.00001$). Effect size for RR interval data were significantly heterogeneous. Subgroup analysis revealed significantly smaller responses of RR interval to training in older subjects ($p < 0.1$). Effect sizes for change in HF were homogenous, although a trend toward an attenuated response to training was exhibited in older subjects ($p > 0.10$). Linear, quadratic and cubic fits all revealed weak ($p > 0.05$) relationships between effect sizes for change in HF and RR interval. Exercise training results in significant increases in RR interval and HF power. These changes are influenced by study population age. The smaller effect size for HF and weak relationship between HF and RR interval suggest factors additional to increased vagal modulation are responsible for training bradycardia.

In order to investigate overtraining-related adaptations in the autonomic nervous system, cardiac autonomic activity was examined in a junior cross-country skier who presented with reduced performance in competitions, early breathlessness during training

sessions, and accumulated central fatigue. Power spectral analysis of heart rate variability (HRV) was performed before, when over trained (TO), and after recovery (Rec). In the over trained state, high frequency (HF) and total powers in the lying position were higher compared with before and after. In normalized units, the increased HF in OT was even more prominent and clearly higher than in any control subject, and it was reversed in Rec. Resting heart rate was slightly reduced in OT and returned to baseline in Rec. The shift toward increased heart rate variability, particularly in the HF range, together with a reduced resting heart rate suggests a cardiac autonomic imbalance with extensive parasympathetic modulation in this athlete when over trained.\textsuperscript{77}

The assumption that tachycardia during light to moderate exercise was predominantly controlled by withdrawal of cardiac parasympathetic nerve activity but not by augmentation of cardiac sympathetic nerve activity (CSNA) was challenged by measuring CSNA during treadmill exercise (speed, 10 to 60 meter/minute) for one minute in five conscious cats. As soon as exercise started, CSNA and heart rate (HR) increased and mean arterial pressure (MAP) decreased; their time courses at the initial 12 seconds period of exercise were irrespective of the running speed. CSNA increased 168 to 297\% at 7.1 $\pm$ 0.4 s from the exercise onset, and MAP decreased 8 to 13 mmHg at 6.0 $\pm$ 0.3 s, preceding the increase of 40 to 53 beats/minute in HR at 10.5 $\pm$ 0.4 second. CSNA remained elevated during the later period of exercise, whereas HR and MAP gradually increased until the end of exercise. After the cessation of exercise, CSNA returned quickly to the control, whereas HR was slowly restored. In conclusion, cardiac sympathetic outflow augments at the onset of and during dynamic exercise even though the exercise intensity is low to moderate, which may contribute to acceleration of cardiac pacemaker rhythm.\textsuperscript{78}

Heart rate variability and post exercise heart rate recovery are used to assess cardiac parasympathetic tone in human studies, but in some cases these indexes appear to yield discordant information. Pyridostigmine, an acetyl cholinesterase inhibitor that


selectively augments the parasympathetic efferent signal, to further characterize parasympathetic regulation of rest and post exercise heart rate was utilized. Time and frequency domain indexes of resting heart rate variability and post exercise heart rate recovery in 10 sedentary adults and 10 aerobically trained athletes after a single oral dose of pyridostimine (30 mg) and matching placebo in randomized, double-blind, crossover trial were measured. In sedentary adults, pyridostimine decreased resting heart rate [from 66.7 (SD 12.6) TO 58.1 beats/minute (SD 7.6), p = 0.005 vs. placebo] and increased post exercise heart rate recovery at one min [from 40.7 (SD 10.9) TO 45.1 beats/minute (SD 8.8), p = 0.02 vs. placebo]. In trained athletes, pyridostimine did not change resting heart rate or post exercise heart rate recovery when compared with placebo. Time and frequency domain indexes of resting heart rate variability did not differ after pyridostimine versus placebo in either cohort and were not significantly associated with post exercise heart rate recovery in either cohort. The divergent effects of pyridostimine on resting and post exercise measures of cardiac parasympathetic function in sedentary subjects confirm that these measures characterize distinct aspects of cardiac parasympathetic regulation. The lesser effect of pyridostimine on either measure of cardiac parasympathetic tone in the trained athletes indicates that the enhanced parasympathetic tone associated with exercise training is at least partially attributable to adaptations in the efferent parasympathetic pathway

Both the components (PNS and SNS) of ANS collectively or singularly undergo adaptive changes in the trained population. The changes in ANS take place with the changes in intrinsic factors or without them. The PNS activity is found to be

increased in physically trained while SNS activity may decrease or does not change at all with training. Changes in parasympathetic mechanisms probably cannot occur without changes in sympathetic system. Changes in parasympathetic mechanisms probably cannot occur without changes in sympathetic system. Vagus influence is capable of dominating the sympathetic in the control of heart rate.

The conducted study explored the possibility of short duration of supervised physical training on cardiovascular performance and attempted to look into the change in the autonomic tone as assessed by heart rate variability (HRV), if any. The study was conducted on 25 healthy adult male subjects (mean age: 32.08 ± 8.32 years) who underwent 15 days of moderate physical training on bicycle ergometer. Heart rate and blood pressure response to exercise and during recovery was monitored as well autonomic activity (tone) was assessed by heart rate variability in resting condition and all the parameters were compared before and after physical training of 15 days. Heart rate response to graded exercise on bicycle ergometer showed a significant decrease at second minute, forth minute, fifth minute and sixth minute during exercise after physical training and systolic blood pressure response also showed a significant decrease at 4th minute, fifth minute and sixth minute during exercise after physical training. Physical training resulted in quick recovery during the first minute after cessation of exercise (percentage drop 21.03 ± 7.93 vs. 23.50 ± 6.97, p < 0.05). Although there was no significant change in the HRV parameters, there was a trend reflecting an increase in parasympathetic tone and decrease in sympathetic tone after physical training. It was concluded from the conducted study that even a short duration of physical training results in favorable cardiovascular performance adaptation and it may be ascribed to autonomic modulation.

The study reports the results of 15 days of exercise training in 25 adult males on cardiovascular autonomic response amplitude and latencies. A standard battery of autonomic function tests including both activity (tone) and reactivity was used.

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Parasympathetic activity evaluated from heart rate variability (HRV) showed no statistically significant change in both, time and frequency domain measures, similarly sympathetic activity measured by QT/QS2, ratio showed no statistically significant change, but there was a trend of decrease in sympathetic activity as evaluated by diastolic blood pressure response. Time domain assessment of autonomic responses was done by measuring tachycardia and bradycardia latency during LST and a decrease in bradycardia latency during VM. It was concluded from the resent study that 15 days of physical training is not enough to alter autonomic activity and PNS reactivity but can result in changes in SNS reactivity and and latency parameters. It was hypothesized that a decrease in bradychardia latency during VM and a decrease in tachycardia latency during LST denotes a delayed activation of the system both of which are favorable cardiovascular responses.

Physical Training could lead to various autonomic changes. It might change the activity (tone) of the individual components of ANS and thereby changing the baseline itself. It also can change the autonomic reactivity to certain stimuli in general which could determine the cardiac performance in response to a given stimuli. Physical training leads to improvement in the cardiovascular functions by altering the neural and non-neural control. Reduction in heart rate is one of the known facts of the endurance training. A number of studies conducted on humans dogs.

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Chapter II

Review of the Related Literature

Rats\(^{99,100,101}\) and horses\(^{102}\) have shown that endurance exercise training causes resting bradycardia. In a study conducted\(^{103}\) on physically trained middle-aged population reported training bradycardia after a training programme of ten months. However few studies showed no change in resting heart rate after physical training. Frick\(^{104}\) observed no change in resting heart rate with two months of extensive; however the heart rate at sub maximal workloads was decreased.

Wilmore (1996)\(^{105}\) reported minimal effect of 20 weeks of physical training on resting heart rate. In hypertensives also, after six months of regular a physical training no change in resting exhibit lesser increase in heart rate during exercise.\(^{106,107,108}\) Studies have shown that regular engagement in physical training leads to changes in cardiovascular autonomic. Aim of the study was to investigate the effect of physical training on autonomic function and opiate withdrawal score in upload dependence syndrome patient during post-detoxified period. Before recording the parameters, the patients (age 31 \(\pm\) 8.4 years) were detoxified with buprenorphine or dextroproxyphene for nine days. Then they were randomized into physical training (PT, n= 22) and control \(\pm\) bicycling a day for two weeks. The load of exercise was based on heart rate that was kept between 110 to 130 beats per minute. The other group did no exercise.

\(^{101}\) K Sigvardsson, E Svanfeldt and A Kilborn; “Role of the Adrenergic Nervous System in Development of Training included Bradycardia”, \textit{Acta Physiol Scand.}, 1977, 101 : 481-8
The autonomic function and operate withdrawal scores were recorded before and after the training period. The autonomic function was assessed using standard battery of five reflex tests (deep breathing, valsalva manoeuvre, lying to standing, cold pressure and hand grip) and activity measurement (heart rate variability and QS/QS ratio). The presented are either mean ± SD or median (range). All patients consented for the study and ethics committee the institute approved the study protocol. The short term physical training in PT resulted in withdrawal symptoms when compared within the group \([7(0-19) \text{ vs. } 1(0-7)] \ p < .01\) and with CT \([4(0-11) \text{ vs. } 1(0-7) \ p < .01]\). The PT group showed significantly high resting heart rate \((78.2 \pm 8.3 \text{ vs. } 72.1 \pm 10 \text{ bpm, } p < .05)\), and mean arterial pressure \((\text{MAP } 113.04) \pm 9.49 \text{ vs. } 105.6 \pm 7.86 \text{ mmHg, } p < .05)\) in comparison to CT. In intra group comparison, they also had significantly decreased heart rate variability [normalized unit of high frequency band \([19.58 (2.96 - 49.23) \text{ vs. } 19.55 (3.19-36.22), p < .05]\), SDNN (mess) [447.28 (23.26-96.86) vs. 40.1 (18.17-83.94, p < .05)] CV \([5.74(3.31-10.21) \text{ vs. } 4.43(2.42-9.95), p < .05]\), SDSD (msec) [163.41(0.97-7.2) vs. 147.17(0.2-1.7), p < .05] in handgrip test the MAP difference (data) was decreased \((27.89 \pm 10.2 \text{ vs. } 22 \pm 7.58 \text{ mmHg, } p < .05)\) in comparison to CT. The absolute MAP response to lying to standing was increased \((116.95 \pm 12.34 \text{ vs. } 109 \pm 10.99 \text{ mmHg, } p < .05)\).

There were no difference in parasympathetic reactivity ratios (valsalva, 30:15 and E:1) and in QT/QS ratio. It was concluded that short term physical training in opioid dependents during post-detoxified period causes increased sympathetic activity with reciprocal vagal activity. It also decreases sympathetic activity and opiate withdrawal symptoms possibly by eliminating the residual exogenous opioid activity.\(^{109}\)

The study was performed on 1080 school children initially recruited to the conducted study. In all 24 physically active and 24 inactive obese children \((\geq 120\% \text{ of the standard body weight})\) were chosen as samples. Then, 24 lean-active and 24 lean-inactive children, who were matched individually in age, gender, height, and the amount of sports activity, were carefully selected from the remaining children. Physical

activity was classified as the frequency of participation in after school sports activities (active; ≥ 3 times per week, inactive; nothing). The ANS activities were measured during the resting condition by means of heart rate (HR) variability power spectral analysis, which enables us to identify separate frequency components, that is, low frequency (LF; 0.03-0.15 Hz), reflecting mixed sympathetic (SNS) and parasympathetic nervous system (PNS) activity, high frequency (HF; 0.03-0.05 Hz), mainly associated with PNS activity, and total power (TP; 0.03-0.05 Hz), evaluating the overall ANS activity. The spectral powers were log transformed for statistical testing. The lean-active group demonstrated lower resting HR as well as significantly higher TP, LF, and HF powers compared to the remaining groups. In contrast, the obese-inactive group showed significantly lower TP (p < 0.05 vs. the remaining groups) LF (p < 0.05 vs. the lean groups), and HF power (p < 0.05 vs. the lean groups), respectively. The obese-active and lean-inactive groups were nearly identical in all spectral parameters. The correlation analysis revealed that TP among 48 inactive children was significantly and negatively associated with the percentage of body fat (r = -0.53, p < 0.001); however, such correlation among 48 active children was modest (r = -0.33, p = 0.02). Our data suggest that obese children possess reduced sympathetic as well as parasympathetic nervous activities as compared to lean children who have similar physical activity levels. Such autonomic reduction, associated with the amount of body fat in inactive state, might be an etiological factor of onset or development of childhood obesity. On the other hand, regular physical activities could contribute to enhance the overall ANS activity in both lean and obese children. These findings further imply that regular physical activity might be effective in preventing and treating obesity beginning in the childhood.  

This study was designed to investigate the effects of 12 weeks of exercise training on autonomic nervous system (ANS) in 18 obese middle-aged men (N = 9) and women (N = 9) (age: 41.6 ± 1.2 year; BMI: 27.3 ± 0.4 kg m⁻²; % fat: 29.6 ± 1.3%, mean ± SE). Each subject participated in aerobic exercise training at anaerobic threshold (AT), consisting of 30 minutes/session, three times per week for 12 consecutive weeks.

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The ANS activities were assessed by means of power spectral analysis of heart rate variability (HRV) at resting condition before, at five weeks, and after the exercise program. The exercise training resulted in a significant decrease in body mass, BMI, and % fat (p < 0.01) but not in lean body mass (p > 0.05) together with a significant increase in the AT O₂ (p < 0.01). Power spectral data indicated that there were significant increases in the low-frequency component associated with the sympathovagal activity (0.03-0.15 Hz, 348.5 ± 66.8 vs. 694.7 ± 91.5 ms², p < 0.01), the high-frequency vagal component (0.15-0.4 Hz, 146.3 +/- 30.4 vs. 347.7 ± 96.5 ms², p > 0.05), and the overall autonomic activity as evaluated by total power (0.03-0.4 Hz, 494.8 ± 88.5 vs. 1042.4 ± 180.9 ms², p < 0.01) of HRV after the training. Twelve weeks of exercise training has significantly improved both the sympathetic and parasympathetic nervous activities of the obese individuals with markedly reduced ANS activity, suggesting a possible reversal effect of human ANS functions. These favorable changes may also have an influence on the thermoregulatory control over the obesity.¹¹¹

Aging associated changed in sympatho-vagal activities have been widely studied. However, little is known about the association between cardio respiratory fitness level and cardiac autonomic nervous activities in conjunction with baroreflex sensitivity in healthy older men. An incremental sub maximal exercise test in 24 healthy, older men aged 60 to 70 years was performed. They were divided into physically fit (PF, oxygen uptake at anaerobic threshold [ATvO₂] = 25.2 ± 0.85 ml·kg⁻¹·min⁻¹) and physically unfit (PU, ATvO₂ = 19.6 ± 0.42 ml·kg⁻¹·min⁻¹) groups, based upon the results of an incremental exercise stress test. The cardiac autonomic nervous system (ANS) activities were assessed by means of power spectral analysis of heart rate variability. Baroreflex sensitivity (BRS) testing was performed using simultaneous beat-by-beat blood pressure and heart rate measurement during a transition from supine horizontal position to 60° head-up-tilting (HUT). At rest conditions, the high-frequency component (p = .03) and total power (p=.04) of heart rate variability spectrum were significantly higher in the PF group. The BRS assessed during passive HUT was also significantly higher ( 7.5 ± 0.5 vs. 3.0 ± 0.4 ms·mm Hg⁻¹, p = .001) in the PF compared with the PU group. In addition,

a significant correlation coefficient ($r = .73$, $p = .001$) was found between ATvO$_2$ and BRS among the subjects. The maintenance of high cardio respiratory function, i.e., higher ATvO$_2$ through a life-long active lifestyle including endurance exercise, may play an important role in reserving cardiac ANS and BRS in older men.$^{112}$

The aim of the study was to assess the influence of body posture on post-submaximal exercise parasympathetic reactivation and to examine whether this influence was preserved under a heightened sympathetic background. On four occasions, eleven moderately trained subjects (22.1 ± 3.00 years old) performed, in random order, two consecutive submaximal running bouts (CTs), each followed by five minute passive recovery in an upright (Up), sitting (Sit), supine (Sup) or supine with legs up position (SupLu). Between both CTs, participants performed 150 second of supramaximal intermittent running (Sl). Parasympathetic reactivation was assessed from heart rate recovery (HRR) and variability [HRV; e.g. RMSSD (30 second)] indices calculated during the five minute recovery periods [i.e. before (N) and after Sl (post-Sl)]. Sup position was associated with a faster and greater increase in RMSSD (30 second) than Sit and SubLu (both $p < 0.01$), which were all higher compared with Up ($p< 0.001$). A ‘time’ effect was shown in Sit, Sub and SupLu (all $p < 0.05$), but not in Up ($p = 0.99$). All N values were higher than post-Sl values ($p<0.001$), except for Up, where a trend was apparent ($p = 0.06$). In the post-Sl condition, a position effect was preserved for HRR ($p < 0.001$), but not for HRV indices [$p = 0.99$ for RMSSD (30 second)]. In conclusion, the supine position accelerated and increased parasympathetic reactivation more than the other three positions, but the posture effect was less evident following supramaximal exercise. In the context of an accentuated sympathetic background (i.e. post-Sl), post exercise HRV indices are less gravity dependent than HRR, reflecting more the exercise-related changes in parasympathetic activity.$^{113}$

The rhythmic components of heart rate variability (HRV) can be separated and quantitatively assessed by means of power spectral analysis. The powers of high

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frequency (HF) and lower frequency (LF) components of HRV have been shown to estimate cardiac vagal and sympathetic activities. The reliability of these spectral indices as well as that of LF/HF ratio as a marker of autonomic interaction at rest and during exercise is briefly reviewed. Modifications in autonomic activities induced by different physiological conditions, e.g. hypoxia exposure, training and water immersion, have been found in HRV power spectra at rest. The changes in HF and LF powers and in LF/HF ratio observed during exercise have been shown not to reflect the decrease in vagal activity and the activation of sympathetic system occurring at increasing loads. HF peak was recognized in power spectra in the entire range of relative intensity, being responsible for the most part of HR variability at maximal load. LF power did not change during low intensity exercise and decreased to negligible values at medium-high intensity, where sympathetic activity was enhanced. There was no influence from factor such as fitness level, age, hypoxia, and blood distribution. In contrast, a dramatic effect of body position has been suggested by the observation that LF power increased at medium-high intensities when exercising in the supine position. The increased respiratory activity due to exercise would be responsible of HF modulation of HR via a direct mechanical effect. The changes in LF power observed at medium-high intensity might be the expression of the modifications in a arterial pressure control mechanisms occurring with exercise. The finding of opposite trends for LF rhythm in supine and sitting exercises suggests that different readjustments might have occurred in relation to different muscular inputs in the two positions.114

2.13. Conclusions Drawn from the Review of the Related Literature

2.13.1. Effect of Kapalbhati on Autonomic Nervous System

1. Kennedy et al. (1993) found that a unique unilateral effect on sympathetic stimulation of the heart that may have therapeutic value.

2. Stancák et al. (1991) observed that the occurrence of both frequency components in respiration during kapalbhati, which supports the hypothesis about the integrative role of cardiovascular and respiratory rhythms in physiological states characterized by altered respiratory frequency.

3. Kuna et al. (1991) observed that decreased cardiac vagal tone during kapalbhati which was due to changes in respiratory pattern and due to decreased sensitivity of arterial baroreflex. He also revealed that decreased respiratory rate and increased systolic blood pressure and low-frequency blood pressure oscillations after kapalbhati suggest a differentiated pattern of vegetative activation and inhibition associated with kapalbhati exercise.

2.13.2. Effect of Kapalbhati on Different Physiological Variables

1. Gharote (1990) found that from biochemical point of view the practice of kapalabhati (KB) seems to promote decarboxylation and oxidation mechanisms due to which quieting of respiratory centres is achieved, which is also the prerequisite for the practice of pranayama, another important technique of yoga.

2. M. Kuna et al. (1991) found a relative increase of slower EEG frequencies and relaxation on a subjective level as the after effect of KB exercise.

3. Joshi and Telles (2008) concluded that both practices (HFYB and Breath awareness), though very different, influenced the P300. High frequency yoga breathing (HFYB) reduced the peak latency, suggesting a decrease in time needed for this task, which requires selective attention. Breath awareness increased the P300 peak amplitude, suggesting an increase in the neural resources available for the task.

2.13.3. Effect of AnulomVilom and Nadishodhana Pranayama on Autonomic Nervous System

1. Nagarathna et al. (1996) observed that surya anuloma viloma has a sympathetic stimulating effect. This technique and other variations of unilateral forced nostril breathing deserve further study regarding therapeutic merits in a wide range of disorders.

2. Bhargava, Gogate and Mascarenhas (1988) concluded that nadi shodhana pranayama (breathing exercises) appear to alter autonomic responses to breath holding probably by increasing vagal tone and decreasing sympathetic discharges.
3. Raghuraj and Telles (2009) observed that unilateral nostril yoga breathing practices appear to influence the blood pressure in different ways. These effects suggest possible therapeutic applications.


5. Jain, Srivastava and Singhal (2005) found that there are no sharp distinctions between effects of right nostril breathing and left nostril breathing either acute exposure (15 min) or after training (eight weeks). However, there is a general parasympathetic dominance evoked by both these breathing patterns.

2.13.4. Studies on Breathing, Relaxation, Meditation and Autonomic Nervous System

1. Takeuchi and Hayano (1994) concluded from this research that enhanced cardiac parasympathetic tone may explain an important mechanism underlying the beneficial effect of the relaxation response.

2. Travis et al. (2001) revealed that monitoring patterns of physiological variables may index dynamically changing inner experiences during meditation practice. This could allow a more precise investigation into the nature of meditation experiences and a more accurate comparison of meditation states with other eyes-closed conditions.

3. Corby, James, Roth, Zarcone and Kopell (1984) concluded from this research that sudden autonomic activation was observed that was characterized by the meditator as an approach to the Yogic ecstatic state of intense concentration. These findings challenge the current “relaxation” model of meditative states.

4. Wallace (1999) revealed from this research that the rapid shift in physiological functioning within the first minute might be mediated by a “neural switch” in prefrontal areas inhibiting activity in specific and nonspecific thalamocortical circuits. The resulting “restfully alert” state might be sustained by a basal ganglia-corticothalamic threshold regulation mechanism automatically maintaining lower levels of cortical excitability.
5. Kubota, Sato, Toichi, Murai, Okada, Hayashi and Sengoku (2001) observed that both sympathetic and parasympathetic indices were increased during the appearance of Fm theta compared with control periods. Theta band activities in the frontal area were correlated negatively with sympathetic activation. The results suggest a close relationship between cardiac autonomic function and activity of medial frontal neural circuitry.

6. Wallace (1997) from this first experimentation marked three phases during a transcendental meditation session in 16 individuals. Interrater reliability between participant and experimenter classification of experiences at each bell was quite good. During phases including transcendental consciousness experiences, skin conductance responses and heart rate deceleration occurred at the onset of respiratory suspensions or reductions in breath volume. In the second experiment, this autonomic pattern was compared with that during forced breath holding. Phasic autonomic activity was significantly higher at respiratory suspension onset than at breath holding onset. These easily markers could help focus research on the existence and characteristics of consciousness.

2.13.5. Studies on Breathing, Relaxation, Meditation, Heart Rate Variability and Brain Activity

1. Shaw and Jain (2009) concluded that heart rate variability (HRV) measurements to assess mental trainability by progressive relaxation training (PRT) were found to be useful.

2. Satyanarayana et al. (1992) revealed that santhi kriya practice for 30 days reduces body weight and increases calmness.

3. Friedman and Lisa (2002) concluded that engaging in even one brief period of zen breath meditation awareness can be effective for improving the heart’s response to stress for patients with coronary artery disease.

4. Sasaki and Saito (1999) revealed that increased oscillation amplitude during slow breathing is caused by resonance between cardiac variability caused by respiration and that produced by physiological processes underlying slower rhythms. The rhythm irregularities during inhalation may be related to inhibition of vagal modulation during the cardioacceleratory phase. It is not known whether they reflect cardiopathology.
5. Halámek et al. (2003) concluded that the frequency of 0.10 Hz represents a useful and potentially important one for controlled breathing, at which differences in blood pressure–RR interactions become evident.

6. Shaw and Jain (2009) revealed that Heart Rate Variability (percentage change of HRV activity and reactivity due to PRT) is a valid method (criterion measures) to evaluate the effect of PRT on sportspersons with four groups of extreme personality dimensions.

2.13.6. Effect of Breathing Exercises and Pranayamas on Different Physical, Physiological Including Autonomic Variables


2. Subbalakshmi, Saxena et al. (2005) suggests that ‘nadi-shodhana pranayama’ rapidly alters cardiopulmonary responses and improves simple problem solving. Further studies on a larger sample size need to illustrate the underlying mechanisms involved in this alteration.


4. Pramanik, Sharma. et al. (2009) noted that slow pace bhashrika pranayama (respiratory rate 6/minutes) exercise improving the autonomic nervous system through enhanced activation of the parasympathetic system.

5. Raghuraj et al. (1996) concluded that practice of pranayama / nadi shodhana pranayama (alternative nostril breathing) increases hand grip strength without lateralization effect.

6. Hannelore korbel (1993) revealed that relaxation of the respiratory changes can be achieved sooner, but the changes to occur in the sympathetic nervous system will take a long term practice.

7. Joshi et al. (1992) observed that there was decrease in the respiratory rate which they thought that it may be due to a decreased CO2 production and decreased O2 consumption. This produces a wake full hypo-metabolic state in the yogic group.
8. Telles and Desiraju (1992) observed that in Pranayama there are 4 stages, viz. Inspiratory (I), Internal Retention (kumbaka K-I), Expiration (E) and External Retention (kumbaka K-E). This has to be performed in specific ratio. Each type of Pranayama has got different ratio, hence practicing them leads to variations in heart rate.

9. Bhargava et al. (1988) concluded from their research that base line heart rate and blood pressure (systolic and diastolic) showed tendency to decrease and both these autonomic parameters were significantly decreased at breaking point after pranayamic breathing. Although GSR was recorded in all subjects the observations were not conclusive.

10. Udupa et al. (1974) found that the pulse rate decreased more and the blood pressure did vary a bit, but there was a definite change in the autonomic functioning of the body. The breath holding time increased and at the same time the pulse rate also decreased.

11. Gopal et al. (1973) found that six months the yogic and the pranayamic group showed a decrease in the pulse rate in the yogic and the trained group but not very significantly.

12. Udupa et al. (2003) observed that three months of pranayama training modulates ventricular performance by increasing parasympathetic activity and decreasing sympathetic activity.

13. Desiraju et al. (1991) revealed that the short kumbhak pranayamic breathing caused a statistically significant increase (52%) in the oxygen consumption (and metabolic rate) compared to the pre-pranayamic base-line period of breathing. In contrast, the long kumbhak pranayamic breathing caused a statistically significant lowering (19% of the oxygen consumption (and metabolic rate).

14. Murthy et al. (1994) found that those who practised pranayama could achieve higher work rates with reduced oxygen consumption per unit work and without increase in blood lactate levels. The blood lactate levels were significantly low at rest.

15. Berrettini et al. (1978) observed no significant changes in arterial blood gases were noted after Pranayama. A neural mechanism for the mental effects of this practice is proposed.
16. Rai, Balavittal, Thombre and Gitananda (1983) found that a consistent and significant \((p<0.01)\) reduction in \(O_2\) consumption within a few minutes of starting savitri pranayam. During shavasan, there was significant reduction in \(O_2\) consumption \((p<0.05)\), heart rate \((p<0.001)\) and diastolic blood pressure \((p<0.05)\). In untrained subjects, the changes in above mentioned parameters were statistically insignificant.

17. Joshi and Gokhale (1992) observed after short pranayama there was improved ventilatory functions in the form of lowered respiratory rate (RR), and increases in the forced vital capacity (FVC), forced expiratory volume at the end of 1st second (FEV1%), maximum voluntary ventilation (MVV), peak expiratory flow rate (PEFR-lit/sec), and prolongation of breath holding time.

18. Dash and Telles (1998) found that an increase in motor speed for repetitive finger movements following yoga training, but not in strength or endurance, as the increase was not sustained over 30 seconds.

19. Madanmohan et al (2004) found that after yoga training a given level of exercise leads to a milder cardiovascular response, suggesting better exercise tolerance.

20. Madanmohan et al (2003) concluded from their research that yoga should be introduced at school level in order to improve physiological functions, overall health and performance of students.

21. Yadav and Das (2001) observed that yoga practice showed significant increase in FVC, FEV-1 and PEFR at the end of 12 weeks.

22. Sathyaprabha, Murthy and Murthy (2001) observed that the significant improvement in PEFR, VC, FVC, FEV1, FEC%, MVV, ESR and absolute eosinophil count. The patients reported a feeling of well being, freshness and comfortable breathing. Naturopathy and yoga helps in inducing positive health, alleviating the symptoms of disease by acting at physical and mental levels.

23. Muralidhara and Ranganathan (1982) found that statistically significant increase in cardiac recovery index (CRI) as assessed by harvard step test was observed in yoga trained subjects after two and half months of training.

24. Madanmohan et al (1986) observed that changes in heart rate and QRS axis during the inspiratory and expiratory phases of pranayam type breathing were
similar to the changes observed during the corresponding phases of deep breathing.

25. Singh, Tamburinath and Karve (1982) revealed that variety of psychotherapeutic interventions, such as relaxation techniques or yoga training, can lower hypertension.

26. Madanmohan et al (1986) observed that yoga practice for 12 weeks results in significant reduction in visual and auditory RTs and significant increase in respiratory pressures, breath holding times and Hand Grip Strength (HGS).

2.13.7. Effect of Breathing Exercises and Pranayamas on Psychological Variables

1. Block, Arnott, Quigley and Lynch (1989) that observed spatial performance is better during right-nostril breathing, and their verbal performance is better during left nostril breathing. Unilateral breathing influences female performance contralaterally, but only on the spatial task: Their spatial performance is better during left-nostril breathing.

2. Joshi and Telles (2008) found that breathing through the left nostril increased performance in a spatial cognitive task, corresponding to the cerebral hemisphere contralateral to the patent nostril.

3. Brown and Gerbarg (2005) found that Yoga techniques enhance well-being, mood, attention, mental focus, and stress tolerance. Proper training by a skilled teacher and a 30-minute practice every day will maximize the benefits.

4. Balayogi, Madanmohan and Kaviraja Udupa (2003) observed that mukh bhasrrika produced a significant (P<0.01) decrease in visual reaction time (VRT) as well as auditory reaction time (ART). A decrease in RT indicates an improved sensory-motor performance and enhanced processing ability of central nervous system.

5. Joseph et al. (1992) observed that Na-wave amplitude increased and latency decreased during the period of pranayamic practice, whereas the Pa-wave was not significantly altered.

6. Khalsa et al. (1991) observed that Cognitive performance ratios can be influenced by forcibly altering the breathing pattern.
7. Shirley et al. (1997) found that breathing increases spatial rather than verbal scores, without a lateralized effect

8. Rajora and Prajapati (2009) found that four weeks yogic exercises on experimental group did result insignificant difference in the emotional intelligence (EI). But they show the insignificant difference in the intelligence quotient (IQ) level of the students

9. Jella and Shannahoff-Khalsa (1992) found that yogic breathing technique may have useful application in treating psychophysiological disorders with hemispheric imbalances and disorders with autonomic abnormalities

2.13.8. Effect of Specific Postural Asanas on Autonomic Functions

1. Ram et al. (1993) observed that virasana induces temporarily a hypermetabolic state characterised by enhanced sympathetic nervous system activity which gets inhibited during the adoption of resting supine shavasana posture.

2. Telles (2003) found that (i) subjects who practiced the headstand with the support of a wall showed reduced finger plethysmogram amplitude suggesting increased sympathetic vasomotor tone (ii) Practicing the headstand without support was associated with an increase in the skin conductance level, suggestive of increased sympathetic sudomotor tone. Hence, it was concluded that both categories showed similar changes in the HRV components though changes in sympathetic vasomotor and sudomotor activity were different. These changes suggest sympathetic activation, irrespective of the method of practice

2.13.9. Effect of General Yogic Exercises on Autonomic Nervous System

1. Nayar et al. (1983) observed that yogic practice for six months resulted in a trend of shift in the autonomic equilibrium towards relative parasympathodominance, improvement in thermoregulatory efficiency and orthostatic tolerance. It has also brought about improvement in physical performance by minimizing the energy expenditure during submaximal exercise. The changes in the biochemical profile indicated a relative hypometabolic state after six months of yogic practice.
2. Sathyaprabha, Satishchandra et al. (2008) concluded from their research that yoga may have a role as an adjuvant therapy in the management of autonomic dysfunction in patients with refractory epilepsy.

3. Vempatti and Telles (2002) found that sympathetic activity decreased after guided relaxation based on yoga, depending on the baseline levels.

2.13.10. Clinical Studies on Autonomic Nervous System and Heart Rate Variability

1. Bhavanani and Udupa (2002) observed that lying supine with head in different directions has a definite effect on the heart rate and blood pressure.

2. Cysarz, Dirk, Bonin, Lackner, Heusser, Moser and Bettermann (2004) concluded from their research that recitation of hexameter verse exerts a strong influence on RSA by a prominent low frequency component in the breathing pattern, generating a strong cardiorespiratory synchronization.

3. Srinivasan, Vaz and Sucharita (2006) found that there were no significant differences between the two groups on any of the conventional tests of autonomic nervous activity. The low frequency power in normalized units and low frequency high frequency ratio of heart rate variability in supine posture was significantly higher in the “stress” group compared to the “no stress” group. The low frequency power in normalized units was significantly positively correlated with total stress score. The changes were suggestive of a tilt in the resting cardiac autonomic balance towards increased sympathetic activity.

4. McCraty et al. (1993) concluded from their research that that individuals can intentionally affect their autonomic nervous system balance, and thus, their HRV.

5. Madanmohan, Prakash and Bhavanani (2009) concluded from their research that the presence of a statistically significantly correlation between RPP, PP and spectral measures of short-term HRV supports a simplistic approach to as surrogates of HRV when it is not feasible to determine HRV indices directly.
2.13.11. Comparison Between Yogic Exercises and Physical Activities

1. Shome and Bannerjee (2009) observed that hatha yoga, aerobic dance, combined groups increased intelligence, interest, memory and reaction time but it showed that combined group (yoga and aerobic) is better than all the other groups.

2. Thakur and Babdopadhyay (2009) found that yoga asana group was superior to gymnastics group and control group, gymnastic group was also superior to control group.

3. Meshram and Ramtekkar (2007) observed that highest mean FEV$_1$ and PEFR in yogis. Both yogis and athlete had significantly better FEV$_1$ as compared to sedentary workers. Yogis also had significantly better PEFR as compared to sedentary workers and athletes. Yogis and athletes had similar lung functions except for better PEFR amongst yogis. Involvement in daily physical activity or sport preferably yoga can help in achieving better pulmonary function.

2.13.12. Effect of Physical Exercise/ Training on the Functions of Autonomic Nervous System

1. L Soares-Miranda et al. (2000) concluded from their research that vagal modulation is enhanced with high levels of physical training (PA) and that it is the number of bouts of vigorous PA that is most closely associated with cardiac autonomic nervous system (cANS) function.

2. M Buchheit et al. (2009) concluded from their research that the 30 to 15 intermittent fitness test (IFT) is accurate for assessing ventilatory threshold (VThs) and VO$_2$peak, but it alters post exercise parasympathetic function more than a continuous incremental protocol.

3. JJ Peiffer et al. (2009) concluded from their research that the cold water immersion (CWI) can significantly restore the impaired vagal-related HRV indexes observed after supramaximal exercise. CWI may serve as a simple and effective means to accelerate parasympathetic reactivation during the immediate period following supramaximal exercise.
4. D Ataoui et al. (2007) concluded from their research that the elevated initial HF levels could be important in the parasympathetic activity increases during taper and, hence, in swimming performance improvement.

5. GR Sandercock et al. (2005) concluded from their research that the exercise training results in significant increases in RR interval and HF power. These changes are influenced by study population age. The smaller effect size for HF and weak relationship between HF and RR interval suggest factors additional to increased vagal modulation are responsible for training bradycardia.

6. R Heddelin et al. (2000) observed that the shift toward increased heart rate variability, particularly in the HF range, together with a reduced resting heart rate suggests a cardiac autonomic imbalance with extensive parasympathetic modulation in this athlete when over trained.

7. Hirotsugu Tsuchimochi et al. (2002) observed that cardiac sympathetic outflow augments at the onset of and during dynamic exercise even though the exercise intensity is low to moderate, which may contribute to acceleration of cardiac pacemaker rhythm.

8. Thomas A Dewland et al. (2007) observed that the lesser effect of pyridostigmine on either measure of cardiac parasympathetic tone in the trained athletes indicates that the enhanced parasympathetic tone associated with exercise training is at least partially attributable to adaptations in the efferent parasympathetic pathway.

9. AD Jose et al. (1970) observed that even a short duration of physical training results in favorable cardiovascular performance adaptation and it may be ascribed to autonomic modulation.

10. Rajesh K Sharma and KK Deepak (2004) observed that 15 days of physical training is not enough to alter autonomic activity and PNS reactivity but can result in changes in SNS reactivity and latency parameters.

11. MP Chacon-Milkahil et al. (1998) observed that endurance exercise training causes resting bradycardia.

12. MH Frick et al. (1967) observed that no change in resting heart rate with two months of extensive; however the heart rate at sub maximal workloads was decreased.
13. BH Paudel et al. (1999) observed that short term physical training in opioid dependents during post-detoxified period causes increased sympathetic activity with reciprocal vagal activity. It also decreases sympathetic activity and opiate withdrawal symptoms possibly by eliminating the residual exogenous opioid activity.

14. N Nagai et al. (2000) observed that regular physical activity might be effective in preventing and treating obesity beginning in the childhood.

15. M Amano et al. (2001) observed that Twelve weeks of exercise training has significantly improved both the sympathetic and parasympathetic nervous activities of the obese individuals with markedly reduced ANS activity, suggesting a possible reversal effect of human ANS functions.

16. Linda et al. (2000) observed that the maintenance of high cardio respiratory function, i.e., higher ATvO₂ through a life-long active lifestyle including endurance exercise, may play an important role in reserving cardiac ANS and Baroflex sensitivity (BRS) in older men.

17. M Buchhei et al. (2009) observed that the supine position accelerated and increased parasympathetic reactivation more than the other three positions, but the posture effect was less evident following supramaximal exercise. In the context of an accentuated sympathetic background (i.e. post-Sl), post exercise HRV indices are less gravity dependent than Heart Rate Recovery (HRR), reflecting more the exercise-related changes in parasympathetic activity.

18. R Perini and A Veicsteinas (2003) found that opposite trends for LF rhythm in supine and sitting exercises suggests that different readjustments might have occurred in relation to different muscular inputs in the two positions.


A total of 114 studies have been critically documented under twelve subheadings. It is evident that autonomic variables are important for health, life and wellbeing. Autonomic variables are related to the training of specific pranayama (anulom vilom, kapalbhati, nadishodhana), breathing, relaxation, meditation, pranayama in general, specific postural asanas, general yogic exercises, yogic exercise and physical
activity, physical exercise/training, body posture. There are almost no studies on agnisar kriya and bhramari pranayama in relation to autonomic nervous system variables. Further it was identified that there is no study of specific experimental effect of anulom vilom, kapalbhati, bhramari and agnisar on the autonomic variables of women considered as a great research gap. Negligible number of studies has been dedicated to female. The yoga research hardly addressed the female. The women after child birth and before menopause undergo lots of changes and physiological changes between the ages from 35 years to 45 years. The research review suggest that there is a positive effect of kapalbhati on autonomic nervous system, kapalbhati on different physiological variables, anulom vilom and nadishodhana pranayama on autonomic nervous system, breathing exercises and pranayamas on different physical, physiological including autonomic variables, breathing exercises and pranayamas on psychological variables, specific postural asanas on autonomic functions, effect of general yogic exercises on autonomic nervous system, yogic exercises and physical activities, physical exercise/ training on the functions of autonomic nervous system, different clinical studies on autonomic nervous system and heart rate variability. Considering the research gap the research scholar was motivated to experiment on the females age ranging 35 years to 45 years and to study the specific effect of six weeks selected (selected) yogic kriyas/pranayama training on selected autonomic functions.