The nasal cycle is defined as consistent shift in laterality in nasal breathing; as the tissues in one nostril swell, those in the other nostril recede (Keuning, 1968). There is more of airflow in which the mucosa is least swollen. It is an ultradian rhythm and has an alternating patency of 2 to 8 hours. Recent studies by time series analysis detected periods for nasal cycle and co-regulated systems at 280-300, 215-275, 165-210, 145-210, 145-160, 105-140, 70-100, and 40-65 min with the greatest spectral power longer periods during waking (Shannahoff-Khalsa, Kennedy, Yates, & Ziegler, 1996, 1997).

There is always shift in dominance of right and left nostril breathing leading to several physiological and cognitive changes, including lateralized cerebral dominance (Fried, & Grimaldi, 1993). Kayser defined it as “alternation of vasomotor tone throughout the periphery on the two sides of the body” (1895, 1889). The mucosa of the nose is densely innervated with autonomic fibers and the dominance of sympathetic activity on one side produces vasoconstriction, while contralateral nostril exhibits a simultaneous dominance of parasympathetic activity. It is likely that mechanical receptors in the nasal mucosa register the flow of air across the membranes (unilaterally) and transmit this signal ipsilaterally to the hypothalamus; known to be the highest center for autonomic regulation. It is that the pacemaker of the nasal cycle is believed to lie within the superchiasmatic nucleus of the hypothalamus (Mirza, Kriger, & Dorty, 1997). This nucleus receives signals from retino-hypothalamic fibers through eyes and hence regulates various other physiological rhythms to 24 hours light-dark cycle (Ganong, 2005).
Figure 1: Innervation of the nasal mucosa showing neural connection to the brain stem and thoracic spinal segments involved in autonomic regulation.

In ancient texts of yoga and spiritual scriptures breathing process and its regulation were considered very important (Gambhirananda, 1985). Breathing is considered as the grossest form of prāṇa (Sanskrit for subtle life energy). Prāṇa is a combination of two syllables, ‘pra’ and ‘na’, and it denotes constancy; it is a force in constant motion which keeps on expanding and contracting (Swami Muktibodhanada, 1999). Prāṇa is a subtle and vital aspect of the breath (Swara Yoga, 1999). In Vedas and Upaniṣads (Ancient Indian scriptures) the importance of prāṇa is very well known and referred to as a means to attain higher states of
consciousness. Prāṇāyāma is the process by which internal prāṇic store is increased. Prāṇāyāma is comprised of the words ‘prāṇa’, and ‘āyāma’, which means ‘prāṇic capacity or length’. It is merely not breath control, but a technique through which the quantity of the prāṇa in the body is activated to higher frequency (Swami Muktibodhanada, 2001).

In yoga there are several breathing techniques explained to consciously regulate the rate and the depth of breathing, including nostril manipulation. These voluntarily regulated breathing techniques produce varied and discrete effects and are mentioned in various ancient yoga texts. Svara yoga states that breathing through right nostril supposed to be heat generating and that person should carry out energetic activities, such as studying the scriptures, hunting, scaling a fort or a mountain, controlling an elephant, or a chariot (Śiva Svarodaya, chap. V, verses 114-123). In contrast breathing through the left nostril is described as heat dissipating, and it is mentioned that while breathing through the left nostril, one should carry out passive activities such as building a temple, rendering service, cultivating the land, or performing religious rites. In ancient texts of yoga and spiritual scriptures breathing process and its regulation were considered very important (Śiva Svarodaya, chap. V, verses 102-113). It has also been mentioned that when breath flows through both nostrils, one should remain quiet, to be introceptive and avoid any activity (Śiva Svarodaya, chap. V, verses 128). Another
breathing practice known as *Kapālābhiṭi kriya* a cleansing practice involves regulation of rate of breath (Swami Muktibodhanada, 2002) and states that it enhances brain functioning. *Haṭha Yoga Pradīpikā* explains that *praṇa* and mind are intricately linked. Fluctuation of one means fluctuation of other. When either the mind or *praṇa* becomes balanced the other is steadied.

Scientific studies based on these breathing practices have partially been able to scientifically validate descriptions of these practices from ancient texts. A study conducted in 1994 by Telles, Nagarathna, & Nagendra had observed an increase in oxygen consumption. Subsequently another study also showed sympathetic activation, with increased oxygen consumption, systolic blood pressure, and increased cutaneous vasoconstriction (Telles, Nagarathna, & Nagendra, 1996). These results are inline with the ancient description related to right nostril yoga breathing, as heat generating technique.

Studies on alternate nostril yoga breathing have reported that after 4 weeks of practice there is decrease in heart rate and in systolic blood pressure both at rest and when they held their breath until breaking point (Jovanov, 2005). Subsequent study also observed similar results that there is a decrease in breath rate, and as well as an increase in variation in heart rate during phases of breathing (Bhargava, Gogate, & Mascarenhas, 1988). Hence, alternate nostril yoga breathing appears to reduce sympathetic activation. The results of left nostril yoga breathing are still unclear.
Studies on kapalabhāti (KB) have reported that there is shift in sympathetic dominance, a decrease in cardiac vagal tone, decreased respiratory rate suggestive of differentiated pattern of vegetative activation and inhibition (Stancáč, Kuna, Srinivisan, Vishnudevananda, & Dosátlek, 1991; Raghuraj, Ramakrishna, Nagendra, & Telles, 1998). Apart from these effects on oxygen consumption and on autonomic variables, these breathing practices have effect on cerebral electrical activity and on hemisphere-specific tasks. These effects have also been shown during spontaneous shifts in nostril dominance and in unilateral forced nostril breathing.

Studies on spontaneous shifts on nostril dominance have shown an alternating lateralization of the cerebral hemispheric activity in humans. The effect of alternating ultradian rhythms on cognitive performance efficiency was studied by Klein and Armitage (1979). They tested eight subjects with verbal and spatial tasks every 15 min. for 8 hours. They noted an ultradian variation with major peak of activity every 90-100 min. The best performance on the verbal task was 180 degrees out of phase with best performance on the spatial task.

Another study assessed the right-left EEG difference in each of the four major bands correlated well with the nasal cycle. Relatively greater EEG amplitudes were contralateral to the dominant nostril (Werntz, Bickford, Bloom, & Shannahoff-Khalsa, 1983). Spontaneously occurring asymmetries in nasal airflow were correlated with performance in hemisphere specific tasks (Klein, Pilton, Prossner, & Shannahoff-Khalsa, 1986). During a phase of spontaneously occurring
left nostril breathing subjects performed better in a spatial (right-hemispheric) tasks, whereas during spontaneous right nostril breathing their performance was better in a verbal (left hemisphere specific) task. A similar trend of hemispheric activation contralateral to the dominant nostril was observed during unilateral forced nostril breathing. In one study the unilateral airflow was correlated with verbal-spatial task performance in twenty-three right-handed men (Shannahoff-Khalsa, Byole, & Buebel, 1991). In another study, the effect of thirty minutes of unilateral forced nostril breathing was studied in fifty-one right handed volunteers (Jella, & Shannahoff-Khalsa, 1993). Spatial task performance (a right hemisphere specific task) was significantly increased during left nostril breathing, while verbal task performance (a left hemispheric task) showed a trend of increase during right nostril breathing.

However, studies on yoga breathing techniques didn’t report any hemispheric lateralization based on hemisphere-specific tasks. In 1997 a study conducted by Naveen, Nagarathana, Nagendra, & Telles studied the effects of yoga breathing practices on hemisphere specific tasks i.e., verbal and spatial memory task on children. Verbal memory task is a left hemisphere task and spatial memory is a right hemisphere specific task. Subjects were assessed before and after over a ten days period. The children were four group (n = 28), each group practiced different practice. The practices were right-, left-, and alternate-nostril yoga breathing, and control session consisted of breath awareness. There was a significant improvement in spatial memory scores than verbal memory scores
following all yoga breathing practices suggesting right hemispheric activation, showing a lateralized effect.

In 2004 another study conducted to assess the immediate effects of right nostril yoga breathing on bilateral cerebral electrical activity. Right nostril yoga breathing was studied over a period of twenty minutes compared to equal duration of control session i.e., breath awareness in fourteen healthy male volunteers. Study reported during right nostril yoga breathing there was increase in the peak amplitude of Na, and Nb ipsilaterally corresponding to the activity at the mesencephalic-diencephalic, and at the primary auditory cortex respectively. There was significant increase in peak amplitude at the right side suggesting an increase in greater number of neurons recruitment during the practice on the right side.

Study on cerebral hemisphere activity by using an electroencephalogram (EEG) on 11 advanced practitioners during *kapalabhati*, reported increase of slower EEG frequencies and relaxation on subjective level (Stancák, Kuna, Srinivisan, Vishnudevanka, & Dosátlek, 1991). Another study assessed cognitive performance using a cancellation task on medical students, middle-aged, and on older persons. The assessments were made before and after 1 minute of *kapalabhati* and it was shown that there were changes in cancellation scores (either total scores or net scores). This task requires selective and sustained attention, as well as ability to shift attention, hence suggestive of improvement in attention abilities (Telles, Raghuraj, Arankelle, & Naveen, 2008).
The present study was intended to assess the immediate effects of right-, left-, alternate-nostril yoga breathing, as well as on breath awareness, and no-intervention session, and on kapalabhāti (High frequency yoga breathing) on attention using P300 event-related potential (P300 ERPs), on cerebral hemispheric activity using long latency auditory evoked potentials (LLAEPs), on hemisphere specific task using verbal and spatial memory task, and on muscle strength using hand grip dynamometer.

2 RATIONALE OF THE STUDY

2.1 BACKGROUND

The effects of spontaneous shifts in nostril dominance as well as breathing through particular nostril, which could be forced, or part of yoga practice have been studied. In particular, there has been an interest in the effect of uninostril yoga breathing on selective hemisphere specific activity. Most of these studies have examined the performance in hemisphere specific tasks. These tasks usually relate to functions such as spatial localization of objects (right hemispheric task) or manipulation of verbal material (as a left hemispheric task).

There have been no studies whether uninostril yoga breathing influences (i) sensory information processing, and (2) electrophysiological correlates of selective attention in lateralized manner. In order to assess (1) and (2) in the present study (1) Long latency auditory evoked potentials (LLAEPs) and (2) P300 event related