Chapter 3

REVIEW OF LITERATURE
1 Prāṇāyāma: Descriptions from Ancient Indian Yoga Texts
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PRĀṆĀYĀMA

Breathing is an indicator of 'life' in all living entities. It has been mentioned that it is man's sole companion (Śīva Svārodaya, V: 219). However this process is generally ignored as it co-exists as long as a man is alive. It has an underlying significance and subtle importance therefore it is more than a simple physical action.

Upaniṣads which are the essence of Vedas (the ancient Indian scriptures) refer to the process of breathing and its importance as a means to reach the ultimate goal for a spiritual aspirant. The importance of breathing and its diverse effects on human body has been described in an ancient text called Śīva svārodaya, where the original Sanskrit text is available in a comprehensive monograph titled Svāra Yoga by Swami Muktibodhananda (1999). Most of the descriptions in the present review of literature has been obtained from this monograph. Svāra yoga is a science of breathing which enable us to understand the nature of the breath and its influence on the body because the different svāras lead to different types of action at the mental, physical and spiritual levels. The word svāra is referred to the process of the flow of prāṇa. Prāṇa is a Sanskrit word derived from two roots 'pra' is a prefix used to denote constancy and 'ṇa' means 'movement'. Therefore prāṇa is a force (or energy) in constant motion. The gross form of prāṇa which can be normally felt is the flow of the air through either nostrils while breathing. The nature of prāṇa is not static; it expands and contracts (Swami Muktibodhananda, 1999).
Svara yoga mentions that svara changes at regular intervals in a rhythm. In the human body there are three important svaras that are described. They flow in three major subtle energy channels called nādis. These subtle energy channels (nādis) are not anatomically recognized but are described based on experiential observations of the ancient sages. These svaras correspond to three major systems i.e., the mind, life force and spirit or soul. In Svara yoga the mind is known as citta, life force as prāṇa and the spirit as ātmā. Citta controls the five senses: the vision, smell, taste, hearing, and touch. Prāṇa controls the five organs of action: speech, hands, feet, reproductive and excretory organs. Ātmā is the overall witness or controller.

In yoga breathing is considered to be a very important process because it is the most vital means of absorbing prāṇa into the body. In upaniṣads such as Taittiriya, Brāhmaṇa, and Maitri and Śiva Svarodaya, the breath is referred as the vehicle of supreme consciousness (Brahman). In fact Praśnopaniṣat (Ch.3 V:3), which specifically aims at clarifying the nature of creation, explains that "from the self (ātman) is born this Prāṇa. Just as there can be this shadow when a man is there, so this Prāṇa is fixed on the self. He comes to this body owing to the actions of the mind" (Swami Gambhirananda, 1985). It has been explained that Prāṇa is considered as the 'protector'. All things in this world and in the 'heaven' is under the control of Prāṇa. Therefore, Prāṇa is ascertained as an all-pervasive entity which bestows us vitality and intelligence. This has been mentioned in the verse given below:
"All this (in this world), as also all that in the heaven is under the control of Prāṇa. Protect us just as a mother does to her sons and ordain for us splendor and intelligence".

Before beginning prāṇāyāma practices this verse can be recited as paying respect to that life energy because of which we are existing. Hence this verse can be considered as a prayer. Even in the holy Bible it was mentioned that man was given consciousness and life through the breath: "The Lord God formed man of dust from the ground, and breathing into his nostrils the breath of life; and man became a living being" (The Holy Bible, Genesis, 2:6-8).

Svāra yoga mentions there are three major nādis (energy channels) which opens at the right nostril (pingala nādi) and at the left nostril (idā nādi). The channel which lies in the center is suṣumnā nādi. According to yoga texts there are 72,000 nādis and among them the three nādis mentioned above are most important. The word nādi comes from the Sanskrit root nāda which means resonance. The flow of prāṇa in the energy channels (i.e., nādis) are resonating. Hence prāṇāyāma is regulating the process of flow (svāra) of vital energy (prāṇa) through the energy channels (nādis).
The literal meaning of prāṇayāma; prāna is 'vital energy' or 'life force' and ayāma is 'to prolong'. To understand in a simple way prāṇayāma is voluntary regulation (slowing and prolonging) of breathing.

Before describing about these prāṇayāma techniques it is important to understand the effects of three major nādis which have been already described earlier.

Idā nādi is supposed to be a negative channel and brings consciousness into every part of the body. According to Śiva Svarodaya the energy in this channel is similar to the energy of the moon. Hence it is also known as candrabhujā. Its effects on the body are supposed to be 'cooling' 'relaxing' and 'introverting'. The energy fields of idā govern the left side of the body. To control the energy of idā nādi the breath in the left nostril is manipulated. Pīngalā nādi is the transmitter of vital energy (prāṇa). Since its energy is positive and invigorating as the rays of the sun, it is called as sūryanādi. Its energy activates the physical body and increases awareness and its energy governs the right side of the body. To control the energy of this nādi the breath in the right nostril is manipulated. Susumna nādi emerges from the base of the spine without diverging on either sides of the body. The energy in this channel is supposed to be neutral. When this channel is active, the breath flows through both nostrils. It has mainly spiritual importance and hence considered as a powerful channel. In summary, when the svāra flows through the left nostril indicates that the mental forces are active. When the svāra flows through the right nostril indicates that
the physical forces are active and when the svara flows through both nostrils simultaneously indicates the spiritual energy is in power.

The importance of prāṇayāma has been described in various ancient Indian texts. Some important descriptions of prāṇayāma in general have been taken from essential texts and are given below.

In Patañjali Yoga Sūtra, prāṇayāma is defined as:

\[
\text{तस्मिन्सति स्वासप्रशास्योगतिविच्छेदः प्राणायामः: ॥}
\]

\[
\text{Tasminsati śvāsaprāśvasayorgativicchedāḥ prāṇāyāmaḥ.}
\]

\[(Patañjali Yoga Sutras: 2.49)\]

"Regulation of breath or the control of prāṇa is the stoppage of inhalation and exhalation, which follows after securing that steadiness of posture or seat (āsana)"

(Mehta, 1990).

Prāṇayāma in the real sense according to this aphorism given by sage Patañjali means an interruption between inhalation and exhalation (Mehta, 1990). In the technical Yogic terms, inhalation is known as pūraka, exhalation as recaka and retention as kumbhaka. From the above description, it is clear that kumbhaka alone constitutes prāṇayāma. It is interesting to note here that Patañjali does not use the words recaka (exhalation), kumbhaka (pause) and pūraka (inhalation) anywhere in his sūtras, although he does refer to these actions, even in the verse given below.
The word *pracchardana*, would always mean expulsion and in this aphorism it refers to breath and not to any subtle psychic force or cosmic element. *Vidhāraṇa* means retention. When all three words *pracchardana*, *vidhāraṇa* and *prāṇa* are taken together, this becomes evident that the word *prāṇa* here refers to breath and breath alone (Swami Kuvalayananda, 1983). In this sūtra, *Patañjali* suggested that breathing is one of the measures to control the mind.

"In *prāṇāyāma* the interval is regulated by place, time and number, and is deep and quiet" (Mehta, 1990).

The inhalation and exhalation in *prāṇāyāma* has to be quiet without making noise. Apart from this *Patañjali* mentions about the place, time and number with reference to the retention of breath. In a book on *Rāja Yoga* by Swami Vivekananda (2001) this aphorism has been explained as: "There are three types of process of *prāṇāyāma*; one by which we draw the breath in, another by which we dispel out, and the third is when the breath is held in the lungs, or stopped from entering the lungs.

(Patañjali Yoga Sūtra: 1.34)

(Patañjali Yoga Sūtra: 2.4)
These again, are varied by place and time. Where the prāṇa is held in some particular part of the body is referred to the 'place' and how long the prāṇa should be confined to, in a certain place is referred to the 'time'. It is considered important as certain schools of yoga such as hathayoga, prāṇayāma practices have prescribed ratios of inhalation, exhalation and retention of breath which varies with the level of experience in prāṇayāma.

In Bhagavad Gītā (the song of the divine):

अपाने जुधवति प्राणं प्राणे पाणं तथापरे।
प्राणायामतः रुद्धः प्राणायामपरायणः॥

Apāne juhvati prāṇāṁ prāṇe pāṇāṁ tathāpare.
Prāṇāyāmagati ruddhā prāṇāyamaparāyanah.

(Bhagavad Gītā: 4.29)

"Still others, who are inclined to the process of breath restraint to remain in trance, practice by offering the movement of the outgoing breath into the incoming, and the incoming breath into the outgoing, and thus at last remain in trance, stopping all breathing. This regulates the life-energy" (Bhaktivedanta Swami Prabhupada, 1998).

In prāṇāyāma an aspirant practices breathing in opposite way until the currents are neutralized. When both air currents (pūraka and recaka) are completely stopped, one is said to in kumbhaka. By the practice of kumbhaka, one can increase the duration of life for perfection in spiritual realization (Bhaktivedanta Swami Prabhupada, 1998). Breathing is a direct means of absorbing prāṇa and the manner in
which we breathe sets off *prānic* vibrations that influence our entire being. The aim of 

*prāṇāyāma* is to control *prāṇa*. If one controls the breath or *prāṇa*, the mind is also 

controlled. He who has controlled his mind has also controlled his breath and gets 

liberation. He is free from the cycle of birth and death. 

According to *Vasiṣṭhadarśnam*, *prāṇayāma* practice has been mentioned in context of 

controlling the mind (i.e., withdrawal of senses).

> भाषायांत्र तत्त: कुर्यादन्त: करणशुद्धये।
> इन्त्रयाण्याहरेत्यथायुद्धवेये: शानि: शानि:॥
>
> *Prāṇayāmam* tatah kuryādantaḥ karanasuddhayaye. 
> *Indriyaḥ* aharet pascādviṣayebhyah śanaiḥ śanaiḥ. 
>
> (Vasiṣṭhadarśnam : 3.115)

"Let him (an aspirant) then perform *prāṇayāma* (or control of breath) for purification 

of the internal organ (also the mind and the intellect). Then, let him draw off the sense 

organs from their objects, slowly" (Atreya, 1993).

> चले वाले चल चित्त निमले निम्नल भवेत।
> योगी स्थानुत्तमामोति ततो वायु निरोधये।॥
>
> *cale vāte* *calan* *cittan* *niścalan* *bhavet*. 
> *yogī* *sthanutvamāṇopoti* *tato* *vāyuṁ* *nirōdayet*. 
>
> (Haṭha *Yoga Pradipikā*: 2.16)

"When *prāṇa* moves, *citta* (the mental forces) moves. When *prāṇa* is without 

movement, *citta* is without movement. By this (steadiness of *prāṇa*) the yogi attains 

steadiness and should thus restrain the *vāyu* (air)” (Swami Muktibodhananda, 2002).
This verse from *Haṭha Yoga Pradipikā* also supports the claim that the *prāṇa* and the mind are connected. Fluctuations of one of them (*prāṇa* or mind) leads to fluctuation of the other. Similarly steadiness of one of them leads to steadiness of the other. Two paths of yoga (i.e., *Haṭha Yoga* and *Rāja Yoga*) consider different approach to control the mind. *Haṭha Yoga* believes that controlling *prāṇa* helps in controlling the mind, whereas *Rāja Yoga* believes that controlling the mind helps in controlling *prāṇa*.

The above mentioned verses from ancient Indian texts of yoga basically provides information about the importance of *prāṇayāma* practices and their general benefits primarily focusing on spiritual growth. *Haṭha Yoga Pradipikā*, the text on *haṭha yoga* provides an explanation of every aspect of yoga practices. It explains in greater detail regarding general guidelines to practice yoga breathing techniques, procedure to perform each of these practices and their benefits (Swami Muktibodhananda, 2002). It is also mentioned that if the practices are not taken seriously it may lead to serious health hazards as in the verse given below:

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प्राणायामेन युक्तेन सवरोगायो भवेत् ।
अयुक्तायासयोगेन सवरोगसमुद्भवः ॥
Prāṇāyāmena yuktena sarvarogāyayō bhavet.
Ayuktaḥbhīṣayasayogenā sarvarogasamudbhavaḥ.
(Haṭha Yoga Pradipikā: 2.16)
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"By proper practice of prāṇāyāma, all diseases are eradicated, through improper practice all diseases can arise" (Swami Muktibodhananda, 2002).

In addition, while practicing prāṇāyāmas the state of mind is considered very important. These practices should be done in a 'steady' state of mind. 

प्राणायाम ततः कुप्सित्य सात्त्विकया धिया।
यथा सुसुम्नादीस्या मला: हुष्टि प्रयाति च॥
Prāṇāyāma tataḥ kuryānnityam sāttvikayā dhiyā.
Yathā suśumnādīsthā malāḥ śuddhām prayānti ca.
(Haṭha Yoga Pradīpikā: 2.6)

"Therefore prāṇāyāma should be done daily with a sāttvic state of mind so that the impurities are driven out of suśumnā nādi and purification occurs" (Swami Muktibodhananda, 2002).

During prāṇāyāma practice the mind should be undisturbed. In this state the whole body is receptive. When the mind is disturbed the energy channels are disturbed which leads to irregular flow of vital energy (prāṇa) causing physical and mental disturbances.

The descriptions of prāṇāyāmas from the above mentioned texts it is evident that practice of holding the breath (kumbhaka) is essential. However according to Yoga Vasiṣṭha, it has been mentioned that the benefits of pranayama can be also accomplished through slowing down of inhalation and exhalation.. This was the approach of Vasiṣṭha School of yoga. This gave rise to two distinct schools of prāṇāyāmas based on kumbhaka and non-kumbhaka. The former (i.e., kumbhaka) is
emphasized while practicing breathing techniques in the *Hatha Yoga* school whereas the latter (i.e., *non-kumbhaka*) is emphasized in the *Vasiṣṭha* school where prolongation of breathing leading to natural cessation of the breath is achieved while practicing breathing techniques. (Nagendra, 1998).

According to *Hatha Yoga* there are eight types of *prāṇayāma* (which are also called *kumbhaka*) are mentioned, they are:

*śūryabheda, ujjayī, sīttāri, sītalī, bhastrikā, bhramarī, mūrchā and plāvini*

"The eight kumbhakas are *śūryabheda, ujjayī, sīttāri, sītalī, bhastrikā, bhramarī, mūrchā and plāvini*" (Swami Muktibodhananda, 2002).

The meaning of these practices are: *śūryabheda* *prāṇayāma* is vitality stimulating breathing, *ujjayī* is known as psychic breath, *sīttāri* and *sītalī* are called hissing and cooling *prāṇayāma* respectively, *bhastrikā* is bellows breath, *bhramarī* is known as humming bee breath, *mūrchā* meaning swooning breath and *plāvini* is known as gulping breath.

The science of *prāṇayāma* is a vast subject to describe. However in the present review of literature the important effects of those *prāṇayāma* practices that are studied in this thesis viz., the right-, left-, and alternate nostril yoga breathing
techniques are described below. These descriptions have been obtained from a book 


**Sūryabheda prāṇayāma:**

> आसने सुखदे योगी बद्ध्या चैवासनं ततः ।
> दृष्टनाभ्या समाकृत्य बहि-स्थं पवनं शीनं॥

Asane sukhade yogi baddhva caivaivasanam tatah.
Dakṣanādyā samākṛṣya bahiṣṭhami pavanam śanaiḥ.

_(Hatha Yoga Pradipikā; 2.48)_

"Sitting comfortably, the yogi should become fixed in his posture and slowly breathe the air in through the right nostril" (Swami Muktibodhananda, 2002).

> आकेरशदन्त्वाध्रा नियोधायि कुम्भयेत् ।
> ततः शीनं सत्वनाभ्या रेवतेवपवणं शीनं॥

Ākeśādanakhāgracca nirodhavadhī kumbhayet.
Tataḥ śanaiḥ savyanādyā recayetpavanāṁ śanaiḥ.

_(Hatha Yoga Pradipikā; 2.49)_

"Retention should then be held until the breath diffuses to the roots of the hair and tips of the nails. Then slowly exhale through the left nostril" (Swami Muktibodhananda, 2002).

> कपालशोधनं वातदोषप्रेम क्रमिदोषहृत ।
> पुनःपुनिर्द्वार शुर्यिन्दुसतुकम्॥

Kapālaśodhananm vātadosaghnam krmidosahṛt.
Punahpunaridam kāryan śuryabhedananuttanam.

_(Hatha Yoga Pradipikā; 2.50)_
"Sūryabhedana is excellent for purifying the cranium, destroying imbalances of the wind doṣa (vāta according to Ayurveda) and eliminating worms. It should be done again and again" (Swami Muktibodhananda, 2002).

Sūrya is 'the sun' and it is also refers to pīṇaglā nādi. Bheda is 'to pierce'. In this prāṇayāma pīṇaglā nādi is activated by breathing through the right nostril and exhaling through the left nostril. Energy flow through this nādi is supposed to be 'heat generating'. However in the present thesis this practice is altered i.e., instead of exhaling through the left nostril the exhalation was carried out from the right nostril. Hence breathing was through the right nostril alone while the left nostril kept occluded with the 'mudrā'. This variation is called sūryānuloma viloma. This variation is allowed to practice as this produces same effects as that of sūryabheda (Swami Muktibodhananda, 2002).

In candra bedha prāṇayāma, the inhalation is done through the left nostril and the exhalation is done through the right nostril. Haṭha yoga Pradīpikā (the text on haṭha yoga) does not mention about this prāṇayāma particularly because if the īḍā nādi is activated the mind becomes introvert and lead to lethargic state (Swami Muktibodhananda, 2002). Energy flow through the īḍā nādi is supposed to be 'heat dissipating'. Hence this should be done under the supervision of an experienced teacher (guru). The variant of this practice is called candrānuloma viloma prāṇayāma.
where the breathing is through the left nostril exclusively while the right nostril is occluded. In the present thesis *candrāṇuloma viloma prāṇayāma* is studied.

According to *Hatha Yoga* school, *anuloma viloma prāṇayāmas* are mentioned differently (Iyengar, 2002). These techniques are not commonly practiced. In Sanskrit *loma* is 'hair', *anu* means 'along with' or 'in natural order' and *vi* means 'against' or 'against the natural order'. In *anuloma prāṇayāma* the fingers are used to manipulate the nostrils to regulate the flow of outgoing breath. The actual practice consists of inhalation which is done through open nostrils with or without pauses and exhalation is done either with both nostrils partially open or alternatively with one nostril completely blocked and the other partially closed. This practice helps in cleansing the nasal passages. In *viloma prāṇayāma* inhalation or exhalation is not a continuous process, it is interrupted by several pauses. This may be compared to climbing up or down a tall ladder with a pause at each step. This practice brings a feeling of ease and lightness to the body. In the present thesis *anuloma viloma* techniques were not practiced as mentioned in *hatha yoga* because this requires pausing and retention of breathing. In contrast these techniques were performed according to *Vasiṣṭha* school where retention and pause of breath were not mandatory and these techniques are generally considered safe (Nagendra, 1998). This was adapted at the center (Swami Vivekananda Yoga Research Foundation, Bangalore) where the present study was carried out.
Nādiśodhana prāṇayāma:

बद्धपद्मासनो योगिः प्राणम् चन्द्रेण पूरयेत् ।
धारित्वा यथाशक्ति भुवः सूर्येन रेचयेत् ॥

Baddhapadmasano yogi prānam candreṇa pūrayet.
Dhārayitvā yathāśakti bhuyah sūryena recayet.

(Hatha Yoga Pradipikā; 2.7)

"Sitting in Baddhapadmāsana (a yoga posture), the yogi should inhale through the left nostril and hold the breath to maximum capacity, and then exhale through the right nostril" (Swami Muktibodhananda, 2002).

प्राण सूर्येन चाकृष्ण पूर्वंहुदर्दर्शने ॥
विभिन्तकुम्भकं कृत्वा पुनःचन्द्रेण रेचयेत् ॥

Prāṇaṁ sūryena cākṛṣya pūrvedudaranti śanaiḥ.
Vidhivatkumbhakaṁ kṛtva punaścandreṇa recayet.

(Hatha Yoga Pradipikā; 2.8)

"Then inhaling the right nostril, gradually fill the abdomen, perform kumbhaka as before, then exhale completely through the left nostril" (Swami Muktibodhananda, 2002).

येन त्यजेतेन पीत्या धाराधारितिरोधतः ॥
रेचयेष ततोऽयेन शान्तेन न वेगतः ॥

Yena tyajettena pitvā dhārayedatirdhataḥ.
Recayecca tato nyena śanairova na vegataḥ.

(Hatha Yoga Pradipikā; 2.9)
"Inhale with same nostril through which exhalation was done, hold the breath to utmost capacity and exhale through the other nostril slowly and not forcibly" (Swami Muktibodhananda, 2002).

_Nādiśodhana_ is referred in this thesis as _Nādiśuddhi_. _Sodhana_ means 'to purify', hence _Nādiśodhana_ practice purifies both _idā_ and _pīṇāglā_ _nādis_ (subtle energy channels). Therefore it is called as purifying breathing and helps in restoring the balance between _idā_ and _pīṇāglā_ _nādis_ (Swami Muktibodhananda, 2002).

Generally _prānayāma_ practices are performed using a hand gesture called 'Mudrā'. It is a specific body or hand position which channelizes the energy produced by _āsana_ (physical posture) and _prānayāma_ into various centres, and arouses particular states of mind (Swami Muktibodhananda, 2002). In this thesis _prānayāma_ practices required manipulating nostrils and hence were performed using a hand gesture called 'nāsikā mudrā'. The index and the middle fingers are kept folded, the thumb is used to occlude the right nostril and the ring and little fingers are used to occlude the left nostril. This should be performed using the right hand only. It is important to note that in the present study the _prānayāma_ practices are not practiced with breath retention as mentioned in the ancient texts cited in the present literature review. Instead the _prānayāma_ techniques were practiced without breath retention as prescribed by _Yoga Vasiṣṭha_, which mentions that retention should be effortless as forceful retention may create health disorders (Nagendra, 1998).
Finally it is interesting to note that the *Svara yoga* text specifically mentions that certain activities should be performed according to the activities of the three subtle energy channels (*nādis*) i.e., *īḍā*, *pingalā* and *suṣumnā*. However it is important to note that performing these activities are not mentioned while practicing *prāṇayāmas*. They should be performed while the respective *nādis* are active during spontaneous breathing. When the breath flows through *īḍā*, one should carry out 'passive' activity, for example, building a temple, rendering service, performing arts, practicing yoga, cultivating the land and performing religious rites (*Śiva Svarodaya, V: 102-113*). When the breath flows through *pingalā*, one should perform 'energetic' activities, such as studying the scriptures, hunting, scaling a fort or mountain, controlling an elephant, horse, or chariot (*Śiva Svarodaya, V:114-123*). When the breath flows through *Suṣumnā*, it has been mentioned to avoid any activity except prayer (*Śiva Svarodaya, V:128*). These descriptions from ancient texts make it interesting to understand the physiological effects of breathing through a particular nostril. In the next section of the literature review, scientific studies on the psychophysiological effects of spontaneous breathing, forced uninostril breathing, voluntary regulated yoga breathing (*prāṇayāmas*, specifically including uninostril yoga breathing) have been described.
3.2 A REVIEW OF SCIENTIFIC LITERATURE ON BREATHING WITH NOSTRIL MANIPULATION (SPONTANEOUS, FORCED AND YOGA-BASED)
3.2.1 THE NASAL CYCLE

It is now over hundred years since Kayser (1895) first reported in the scientific literature that the human nasal passages exhibit spontaneous changes in the unilateral nasal airway resistance, this unusual phenomenon is unclear and yet to be understood. Spontaneous, reciprocal changes in unilateral nasal resistance are often referred to as a ‘nasal cycle’ and although this term is now commonly used to describe spontaneous changes in nasal resistance in man and animals, evidence are not sufficient to prove any true periodicity (Flanagan & Eccles, 1997). The literature of the present day generally accepts the views put forward by Heetderks (1927), and Stocksted (1953) that around eighty percent of the healthy population exhibit a regular cycle. Keuning (1968) observed that the nasal cycle is an ultradian rhythm characterized by alternating patency of the left and right nostril, with a periodicity of 2-8 hours. Its classical form requires identical periods and equal amplitude of patency changes with the total airflow remaining unchanged (Gotlib, Samolinski & Arcimovicz, 2002). The nasal cycle is controlled by sympathetic/parasympathetic innervation of the nasal mucosa. When sympathetic activity to one side dominantes, the result is vasoconstriction and thus decongestion on that side, while the enhanced parasympathetic activity on the other side simultaneously results in congestion (Keuning, 1968; Stocksted, 1953). Hence while the nasal cycle is regulated by the autonomic nervous system, the reverse is also true, the nasal cycle in turn influences the autonomic nervous system. The possible mechanism explained is the electrographic activity in the cortex is produced by a neural reflex mechanism in the superior nasal meatus (Kristof, Servit & Manas, 1981). This activating effect could be
elicited by air insufflation into the upper nasal cavity with out pulmonary exercise. Stocksted (1953) and Eccles (1978) have proposed that the hypothalamus may be responsible for regulating the cyclical changes in the nasal resistance. The Pacemaker of the nasal cycle is believed to lie within the suprachiasmatic nucleus of the hypothalamus (Mirza, Kroger & Doty, 1997). Thus the nasal cycle reportedly correlates with a number of ultradian rhythms. This led to further studies on spontaneous unilateral breathing influencing these rhythms. In the studies mentioned below the nasal cycle is also referred as spontaneous breathing.

3.2.1. A Studies on autonomic related phenomena.

A study by Kennedy, Zeigler & Shannahoff-Khalsa (1986) has provided evidence that sympathetic tonus differs greatly between the two sides of the body. They sampled antecubital venous circulation in both arms simultaneously every 7.5 min for periods of 3-6 hours and assayed for catecholamines [epinephrine (E) and nor epinephrine (NE)] and dopamine (D) levels in 6 male subjects. Their ages ranged between 18 – 36 years. Fluctuations in the nasal cycle relatively were shown to correlate significantly with the alternating levels of the NE. This study demonstrates that lateralized shifts in the concentration of neurotransmitters in peripheral circulation. The study on ultradian rhythms of autonomic, cardiovascular and neuroendocrine system in humans demonstrated that the nasal cycle has been coupled to these rhythms (Shannahoff-Khalsa, Kennedy, Yates & Zeigler, 1996), and the authors proposed that all these ultradian rhythms are regulated by the hypothalamus. Similarly in another study by the same authors (1997) presented a new insight for how systems are functionally linked and temporally co-regulated via the
hypothesis. They have shown that the ultradian rhythms of pituitary hormone and catecholamine secretion, cardiovascular function, and fuel regulation (by insulin) are also tightly coupled to the nasal cycle. This study suggests that insulin secretion has a common pacemaker (the hypothalamus) or a mutually entrained pacemaker with the autonomic, cardiovascular, and neuroendocrine systems.

3.2.1.B Studies on EEG and cognitive functions.

Werntz, Bickford, Bloom & Shannahoff-Khalsa (1983) showed that the nasal cycle is coupled to an alternating lateralization of cerebral hemispheric activity in humans. Electroencephalographic (EEG) activity was continuously recorded in 19 students from homologous sites on the two sides of the head. The signals acquired were rectified, integrated, and subtracted for analysis. The right-left EEG difference in each of the four major frequency bands correlated well with the nasal cycle in all students. It was observed that the EEG amplitudes were greater in the hemisphere contralateral to the dominant nostril. Klein and Armitage (1979) first observed the ultradian rhythms of alternating cognitive performance efficiency by studying verbal and spatial skills. They tested 8 subjects with a verbal and spatial task every 15 min for 8 hours. They noted ultradian rhythm variations with a major peak of activity every 90-100 min. Best performance on the verbal task was 180 degrees out of phase with best performance on the spatial task. They observed that adult volunteers who exhibited right-nostril dominance during spontaneous breathing performed better on simple perceptual tasks with verbal information which are known to be carried out by the left hemisphere, compared with subjects whose left nostril was dominant. Similarly during the left nostril dominant phase subjects performed better on simple
perceptual tasks using spatial information inferred to activate the right hemisphere. Similarly Klein, Pilon, Prosser and Shannahoff-Khalsa (1986) used both verbal and spatial cognitive tests to assess performance efficiency during different phases of the nasal cycle. They observed significant relationship between the pattern of nasal airflow during spontaneous breathing and spatial versus verbal performance. Right nostril dominance correlated with enhanced verbal performance, or left hemispheric activity and left nostril dominance correlated with enhanced spatial performance, or right hemispheric activity.

3.2.2 UNILATERAL FORCED NOSTRIL BREATHING (UFNB).

3.2.2.A Studies on autonomic related phenomena.

The ultradian rhythms of lateralized neural activities help to organize the functions of biological systems to meet primary bodily needs. These functions are associated with activities such as work (hunting), rest (healing), eating and many other behaviors that are identified by Kleitman (1961) as defining the basic rest activity cycle (BRAC). Werntz, Bickford, Bloom & Shannahoff-Khalsa (1983) have proposed that the right nostril dominance correlates with the ‘activity phase’ of the BRAC and the left nostril dominance coincides with the ‘resting phase’ of the BRAC. This concept helps to understand the effects of unilateral forced nostril breathing. A study done by Backon (1988) showed that right UFNB significantly increased blood glucose levels and left nostril UFNB reduced the blood glucose levels. This study involved only one subject who alternated between right and left nostril breathing, demonstrating marked increases and decreases respectively with blood glucose levels.
Subsequently Backon and Kullock (1989) showed how unilateral breathing patterns can affect involuntary eye blink rates in one subject with 11 reversals of nostril conditions. They found that right UFNB reduced blink rates and that left UFNB increased voluntary blink rates suggesting that this differential effect reflects lateralized variation in dopamine activity in the two hemispheres. It is also possible that the right UFNB increases the general sympathetic tone, thus minimizing blink rates and that left UFNB increases the blink rates via a more 'parasympathetic state'.

In another study Backon, Matamoros & Ticho, (1989) showed how intraocular pressure can be selectively altered by forced uninostril breathing patterns. There were 12 subjects in this study. Results showed that the right UFNB leads to an average decrease of 23% in the intraocular pressure and that left nostril breathing increases it by an average of 4.5%. This is a further evidence that right UFNB increases the generalized sympathetic tone of the body, and left UFNB increases the parasympathetic state thus correlating with the 'activity cycle' and 'resting cycle' of the BRAC respectively. The sympathetic and parasympathetic branches of the autonomic nervous system each have separate trunks on the two sides of the body and thus affect bilateral structures and organs differentially, where one side or organ is dominant and the other resting in a relative sense (Shannahoff-Khalsa, 1991).

However this differential autonomic nervous system pattern of organ innervation can also have interesting effects on organs that are not represented as bilateral structures for example the heart. Shannahoff-Khalsa & Kennedy (1993) conducted three experiments that employed impedance cardiography to monitor the beat-to-beat effects of UFNB on the heart. Two experiments employing a respiratory rate of 6
breaths/min. and one experiment with a rapid rate (2-3 breaths/sec) of shallow respiration employing a yogic technique called ‘kapalabhati’ showed that the right UFNB (at a rate of 6 breaths/min) increases heart rate compared to left UFNB which lowers the heart rate. The left UFNB showed an increase in the stroke volume and also an increase in end diastolic volume.

3.2.2.B Studies on EEG and cognitive functions.

A study by Wemtz, Bickford, Bloom & Shannahoff-Khalsa (1987) on integration of EEG amplitudes and UFNB on 5 subjects, who breathed through the more congested nostril for 11-20 min, showed that UFNB produces a relative increase in the EEG amplitudes of the contralateral hemisphere. This finding has been attributed to increased mental activity in the contralateral hemisphere which primarily reflects attention to internal processing. Correlating EEG changes with functions, a study on spatial and verbal task performance was done on 126 subjects, using breathing through dominant uninostril breathing (Klein, Pilon, Prosser & Shannahoff-Khalsa, 1986). This showed that there was a tendency for subjects exhibiting baseline right nostril dominance to perform verbal tasks better (relative to spatial performance) than subjects exhibiting left nostril dominance. However there was no effect of forced uninostril breathing on both verbal and spatial task performance. This could be possibly due to the experimental design. Their comparison cognitive task testing was post-UFNB rather than during. These results showed that at least in baseline (not forced breathing) conditions the function of the contralateral hemisphere is enhanced. In contrast, a subsequent study on undergraduate students showed that forced left uninostril breathing increased spatial performance on a cognitive task (Jella &
Shannahoff-Khalsa, 1993). This paper and pencil task tested mental rotation, manipulation and twisting of two- and three- dimensional stimulus objects; however, it did not validate that forced right nostril breathing increased verbal performance on a task modeled after the Miller Analogies and SAT tests. Perhaps the difference in results obtained with normal breathing and with forced unnostril breathing may be related to forced uninostril breathing using an uncomfortable nose plug. In another study the effect of UFNB on both verbal and spatial tests in 23 right handed males ranging in age from 19 – 31 years were studied (Shannahoff-Khalsa, Boyle & Beubel, 1991). The verbal test was modeled after the SAT tests and the Kohs Modified Block Design was used for spatial testing. The results showed that enhanced verbal efficiency or the left hemisphere activity is associated with right UFNB when compared with left UFNB and spatial performance efficiency, or right hemisphere activity. This study is in agreement with the data interpretation of Werntz, Bickford, Bloom and Shannahoff-Khalsa (1983, 1987) which used EEG to show that the alternating rhythms of cerebral hemisphere activity are coupled to the nasal cycle. The above mentioned two studies (Jella & Shannahoff-Khalsa, 1993 and Shannahoff-Khalsa, Boyle & Beubel, 1991) used longer periods of employing UFNB (30 min). Hence the effects were clearer. Another study investigated using this information on performance correlating with gender (Block, Arnott, Quigley & Lynch, 1989). The effect of UFNB on verbal and spatial performance in both males and females was studied. In males, they observed that UFNB influences both spatial and verbal tasks ipsilaterally, whereas in females, UFNB influenced them contralaterally.
3.2.3 VOLUNTARY REGULATED YOGA BREATHING (PRĀṆAYĀMAS)

Prāṇayāmas are specific yoga breathing practices that can be practiced effortlessly for prolonged periods. Prāṇayāma consists of practices using voluntary regulation of breathing by nostril manipulation and other practices without nostril manipulation. It is mentioned in the ancient yoga texts that these practices produce diverse effects in the human body. This made it interesting to study the effects of these practices using various physiological measures.

3.2.3.A General studies on prāṇayāmas.

The earliest study was done by Behanan (1937), who reported an increase in oxygen consumption (OC) by 24.5% during ujjāyi prāṇayāma and by 18.5% in bhastrikā prāṇayāma. Similarly Miles (1964) also measured OC during ujjāyi and bhastrikā prāṇayāmas and a high frequency yoga breathing called kapālabhāti. The OC increased during ujjāyi (32%), bhastrikā (20%) and kapālabhāti (14%). The breath rate decreased by 3 breaths/min following ujjāyi, and bhastrikā prāṇayāmas and an increase of over 4 breaths/min following kapālabhāti. In a single subject who practiced ujjāyi prāṇayāma at different altitude levels, an increase in OC during ujjāyi prāṇayāma by 9% at 520 m above the sea level was reported (Rao, 1968). An increase of 16 % in OC at an altitude of 3800 m was also found. Comparisons were made with levels at low altitude. Bhargava, Gogate & Mascarenhas (1988) studied autonomic responses to breath holding in 20 male healthy volunteers. Breath holding time, heart rate, systolic and diastolic blood pressure, and galvanic skin resistance were recorded when breath was held at different phases of respiration. After initial recordings of the
above mentioned variables, all subjects practiced nādiśodhana prāṇāyāma (alternate nostril yoga breathing) for a period of 4 weeks. The same variables were recorded at the end of 4 weeks and the results compared. Baseline heart rate and blood pressure (systolic and diastolic) decreased and were also significantly decreased at breaking point after prāṇāyāma breathing. Thus prāṇāyāma breathing exercises appear to alter autonomic responses to breath holding probably by increasing vagal tone and decreasing sympathetic discharge. Kumbhak (timed breath holding) is considered as an important phase of the respiratory cycle in prāṇāyāma. There are two categories of kumbhak viz., short and long kumbhak. Oxygen consumption was studied using a closed circuit method of breathing through the Benedict-Roth spirometer. Readings were obtained pre, during and post prāṇāyāmic breathing period. Results revealed that during the short kumbhak there was a significant increase (52%) in OC, in contrast during long kumbhak there was significant reduction (19%) in OC (Telles & Desiraju, 1991). In a single subject, heart rate was studied in different types of pranayamas namely, sāvitrī prāṇāyāma (SP), nādiśuddhi prāṇāyāma (NP), mahatyoga prāṇāyāma (MP) and vībhāga prāṇāyāma (VP). Ratios of inspiration, kumbhak at the end of inspiration, expiration and kumbhak at the end expiration differed. Heart rate showed an overall increase during two prāṇāyāmas i.e., VP and MP, compared to the respective prepranayamic baseline values (Telles & Desiraju, 1992). A study on middle latency auditory evoked potentials (MLAEPs) in subjects practicing ujjāyi and bhāstrika prāṇāyāmas showed that there was an increase in the Na wave peak
amplitude and a decrease in the peak latency of the Na wave. This is interpreted as an indication of a generalized alteration in information processing at the primary thalamocortical level during prāṇayāmas (Telles & Desiraju, 1992).

### 3.2.4 STUDIES ON VOLUNTARY REGULATED YOGA BREATHING (PRĀṆAYĀMAS) WITH NOSTRIL MANIPULATION.

#### 3.2.4.A Studies on autonomic functions.

All the above studies mentioned in the previous section were on prāṇayāma techniques without nostril manipulation. There are studies conducted on prāṇayāma techniques with nostril manipulation using similar background of studies on uninostril breathing (spontaneous and forced) mentioned earlier. A study carried out on 3 prāṇayāmas in which nostril manipulation is voluntary i.e., right nostril yoga breathing (RNYB), left nostril yoga breathing (LNYB) and alternate nostril yoga breathing (ANYB), practiced for a month as 27 breath cycles, for four times a day (Telles, Nagarathna & Nagendra, 1994). Oxygen consumption was significantly higher (37%) in RNYB. Following the LNYB there was a significant increase in galvanic skin resistance (137.7 kilohms), which can be interpreted as a relaxing effect with reduced sympathetic nervous system activity. The immediate effect of 45 minutes of RNYB was also found to be sympathetic activating, with increased OC (17%), systolic blood pressure (mean increase 9.4 mm Hg) and increased cutaneous vasoconstriction (Telles, Nagarathna & Nagendra, 1996). The heart rate variability (HRV) spectrum was studied in two yoga breathing techniques viz., high frequency yoga breathing (kapalabhaṭi) and alternate nostril yoga breathing (nādiśuddhi) in 12 normal male
volunteers (Raghubar, Ramakrishnan, Nagendra & Telles, 1998). During high frequency yoga breathing there was an increase in the low frequency component of the HRV spectrum which is attributed to the sympathetic activity of the autonomic nervous system, whereas in alternate nostril breathing there was a trend of increase in the high frequency component of the HRV spectrum which is attributed to the parasympathetic activity of the autonomic nervous system.

3.2.4.B Studies on muscle strength.

A study was conducted on the effects of prāṇayāma practices using nostril manipulation on muscle strength in 130 school children of 11 and 18 years of age (Raghubar, Nagarathna, Nagendra & Telles, 1997). All children were right handed. Hand grip strength was assessed before and after 10 day yoga training program. During this period children practiced prāṇayāmas consisted of right-, left-, and alternate nostril breathing practiced as 24 breath cycles, four times a day and the control practices consisted of breath awareness and performing hand gesture (mudra) for the same duration without paying attention to breathing. Hand grip strength of both hands showed a significant improvement (ranging from 4.1% to 6.5%) following all three prāṇayāma practices irrespective of the nostril through which the subjects breathed. This study did not show any lateralized effects.

3.2.4.C Studies on EEG, auditory evoked potentials and cognitive functions.

A study was conducted on the effect of alternate nostril yoga breathing on the brain electrical activity using electroencephalograph (EEG) (Stancak & Kuna, 1994). It was observed that in the initial period of this practice there was an increase in the power of beta 1 (12.1 – 16.0 Hz) and beta 2 (16.4 – 30.0 Hz) pointing to increased
cortical excitability whereas prolonged practice showed an increase in the power of alpha band suggesting a counteracting tendency towards cortical synchronization. In this study emphasis was given to the balancing effect of alternate nostril breathing in relation to beta1 band. The authors speculated that beta1 activity in left- and right hemisphere shows general cortical excitability occurring during forced alternate nostril breathing with out any special topographic preference relative to the direction of the nostril airflow. A study was conducted on middle latency auditory evoked potentials (MLAEPS) in right nostril yoga breathing compared to breath awareness in 14 healthy male volunteers (Raghuraj & Telles, 2004). The subjects practiced these techniques for thirty minutes. The MLAEPs were recorded from the right and left symmetrical scalp sites before, during and after the respective practices. There was a significant increase in the peak amplitudes of the Na wave (corresponding to the activity at the mesencephali-diencephalic level) and the Nb wave (corresponding to the activity at the primary auditory cortex) of MLAEP components on the right hemisphere showing an increase in the neural activity in the hemisphere ipsilateral to the nostril breathing. Another study was conducted to understand the effects of the prānayāma practices (consisted of right-, left-, and alternate nostril breathing) and the control practice (consisted of breath awareness) on verbal and spatial memory tasks in 108 school children (Naveen, Nagarathna, Nagendra & Telles, 1997). The children showed an improvement in spatial memory scores (84%) than verbal memory scores following all prānayāma practices irrespective of nostril manipulation suggesting a right hemisphere activating effect. This shows that prānayāma practices did not produce any lateralized effects.
3.2.5 THERAPEUTIC EFFECTS OF YOGA BREATHING PRACTICES.

Freidell (1948) reported the first contemporary clinical trial for UFNB or alternate nostril breathing technique. He found that “diaphragmatic breathing with attention to both phases of respiration and the intervening pauses” coupled with “alternating closing one nostril while inhaling slowly through the other” had profound effects on patients with angina pectoris. In this study all 11 patients experienced relief from symptoms using this breathing practice and were able to eventually curtail the use of nitroglycerin. The consistent and selective effect of forced uninostril breathing in normal subjects on the general pattern of EEG activity in the hemispheres suggests the possibility of therapeutic approaches to states of psychophysiology where lateralized dysfunction has been shown to occur. Flor-Henry (1983) and others have concluded from numerous studies that schizophrenia is associated with greater left cerebral hemisphere dysfunction and that depression and the other affective disorders are associated with greater right hemisphere dysfunction. Shannahoff-Khalsa & Beckett (1996) studied the clinical efficacy of yogic techniques in the treatment of 8 adults with obsessive compulsive disorder (OCD) over one year follow up. Left nostril yoga breathing with voluntary manipulation for 31 min was given along with other yoga practices. Five patients were able to complete the study and showed a remarkable improvement in Yale-Brown Obsessive Compulsive Scale (Y-BOCS), symptom checklist, Perceived Stress Scale and a significant reduction in medication. Following this another study was conducted to study the efficacy of two meditation protocols for treating patients with obsessive compulsive disorder (OCD). Patients were randomized to two groups and blinded to the comparison protocol. They were
matched for age, sex, and medication status. Assessments were made at baseline and after 3 months using the Yale-Brown Obsessive Compulsive Scale (Y-BOCS), Symptoms Checklist-90-Revised Obsessive Compulsive (SCL-90-R OC) and Global Severity Index (SCL-90-R GSI) scales, Profile of Moods scale (POMS), Perceived Stress Scale (PSS), and Purpose in Life (PIL) test. There were 11 adults and 1 adolescent in Group 1 and 10 adults were in Group 2. Their ages ranged between 14-60 years. Group 1 received kundalini yoga meditation protocol (where breathing through the left nostril along with breath retention was practiced for 31 minutes) and Group 2 received relaxation response along with mindfulness meditation technique. After three months of respective practices Group 1 showed significant improvements on the Y-BOCS, SCL-90-R OC and GSI scales, and POMS. Group 2 did not show improvements in any of them. Finally both groups were merged (n= 11) and they were practicing the protocol given to Group 1. They were assessed at 15 month using the scales mentioned above. The group showed a significant improvement on the Y-BOCS (71%), SCL-90-R OC (62%) SCL-90-R GSI (66%), POMS (74%), PSS (39%), and PIL (23%). This study demonstrates that Kundalini yoga techniques along with uninostril breathing are effective in the treatment of OCD.

Wood (1993) employed three different procedures viz., relaxation, visualization and yogic breathing with stretch (pranayamas) in 71 adults to study perceptions of physical and mental energy and positive and negative mood states. It was reported that practicing pranayama for 30 min caused a significant increase in perception of mental and physical energy feelings of alertness and enthusiasm compared to the other two procedures. These practices were simple to learn even for
the elderly and had a markedly ‘invigorating’ effects on perception of both mental and physical energy and increased high positive mood. This shows that in general yoga breathing exercises have shown to be beneficial for overall improvement of health.

The above studies have been demonstrated that autonomic and respiratory variables and metabolic variables have been measured related to the practice of spontaneous shifts in nostril patency, forced unilateral nostril breathing and right nostril yoga breathing. Similarly the electrophysiological (based on EEG and evoked potentials) studies have been carried out in the same practices as those mentioned above. However with respect to yoga breathing practices which involve nostril manipulation there has been no attempt to study the immediate effects of right-, left-, and alternate nostril yoga breathing as compared with suitable control in a group of individuals who practiced each of the techniques on different occasions. Hence the present study attempted to understand the immediate effects of right-, left-, and alternate nostril yoga breathing as compared to breath awareness and random thinking on (i) autonomic and respiratory variables and (ii) middle latency auditory evoked potentials.
Abbreviations used in Table 3.2

ANYB : Alternate nostril yoga breathing
BAW : Breath awareness
BP (S) : Blood pressure (Systolic)
BP (D) : Blood pressure (Diastolic)
BP : Blood Pressure
cm : Centimeter
EKG : Electrocardiogram
EEG : Electroencephalogram
GSR : Galvanic Skin Resistance
HF : High frequency
HR : Heart Rate
HRV : Heart Rate Variability
Hz : Hertz
LF : Low frequency
LNYB : Left nostril yoga breathing
m : months
MLAEPs : Middle latency auditory evoked potentials
μS : micro Siemens
min : Minute
OC : Oxygen Consumption
P : Probability
RNB : Right nostril breathing
RNYB : Right nostril yoga breathing
RR : Respiratory Rate
Ss : subjects
SCL : Skin conductance level
SD : Standard deviation
sec : seconds
UFNB : Unilateral forced nostril breathing
Vs : Versus
Symbols used : ↑ Increase, ↓ Decrease, < Less than, > Greater than,
± Plus or Minus, = Equal to,
<table>
<thead>
<tr>
<th>No.</th>
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<th>Subjects &amp; Experience</th>
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<td>1</td>
<td>Kennedy, Zeigler and Shannahoff-Khalsa 1986</td>
<td>6 males (18-36 yr)</td>
<td>Sampled antecubital venous circulation of both arms simultaneously every 7.5 min for 3-6 hours Assayed catecholamines (Norepinephrine [NE] and Epinephrine[E]) and Dopamine</td>
<td>Fluctuations in nasal cycle correlates with alternating levels of NE in the two arms Shows lateralized shifts in the concentration of neurotransmitters in peripheral circulation</td>
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<tr>
<td>2</td>
<td>Shannahof f-Khalsa, Yates, Zeigler 1997</td>
<td>10 adult Ss (8 males, 2 females) 20-42 yr</td>
<td>Assayed for ACTH, LH, NE, E and insulin Sampled blood every 7.5 min - both arms for the period range – 40-65, 70-100, 115-145, 170-215, and 220-340 min</td>
<td>Neuroendocrine hormonal activity including insulin was maximum in the ranges of 115-145, 70-100, and 40-65 min. These activities are coupled with ultradian rhythm such as the nasal cycle. The common pacemaker for regulating these hormones are proposed to be the hypothalamus</td>
</tr>
<tr>
<td>3</td>
<td>Wernitz, Bickford, Bloom &amp; Shannahof f-Khalsa 1983</td>
<td>19 Ss (5 females)</td>
<td>EEG was recorded continuously from homologous sites on the two sides of the head</td>
<td>Integrated EEG values were greater in the hemisphere contralateral to the dominant nostril during spontaneous breathing</td>
</tr>
<tr>
<td>4</td>
<td>Klein and Armitage (1979)</td>
<td>8 Ss</td>
<td>verbal and spatial task every 15 min for 8 hours</td>
<td>(i) right-nostril dominant phase during spontaneous breathing Ss performed better on simple perceptual tasks with verbal information (ii) left nostril dominant phase Ss performed better on simple perceptual tasks using spatial information</td>
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Studies on unilateral forced nostril breathing (UFNB) and autonomic related phenomenon

<table>
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<tr>
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<th>Techniques Studied and Design of Experiment</th>
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<tbody>
<tr>
<td>1</td>
<td>Backon 1988</td>
<td>1 Ss</td>
<td>Monitored blood glucose levels Ss alternated between right and left nostril breathing several times</td>
<td>Right UFNB ↑ blood glucose levels Left UFNB ↓ blood glucose levels</td>
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<tr>
<td>2</td>
<td>Backon, Kullock 1989</td>
<td>1 Ss</td>
<td>Voluntary eye blink rates 11 reversals of nostril conditions</td>
<td>Right UFNB ↓ blink rates Left UFNB ↑ blink rates Lateralized variation in dopamine activity in the two hemispheres</td>
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<td>3</td>
<td>Backon, matamoros, &amp; Tichon 1989</td>
<td>12 Ss</td>
<td>Monitored intraocular pressure (IOP)</td>
<td>Right UFNB ↓ IOP (23%) Left UFNB ↑ IOP (4.5%) Right UFNB increases generalized sympathetic tone and left UFNB increases the parasympathetic state</td>
</tr>
<tr>
<td>4</td>
<td>Shannahoff-Khalsa Kennedy 1993</td>
<td>7 adults (4 males, 3 females)</td>
<td>In experiment 1- Respiration at 6 breaths/min through congested nostril-15 min, rest period - 15 min and decongested nostril-15 min, followed by rest period - 15 min In experiment 2- rapid yogic breathing at 2-3 breaths cycles/sec Measured heart rate (HR), stroke volume (SV), Index of contractility (IC), Cardiac output (CO), End diastolic volume (EDV), Ejection fraction (EF)</td>
<td>RNB ↑ HR more than the left, LNB ↑ EDV and SV Rapid yogic breathing ↑ HR</td>
</tr>
<tr>
<td>No.</td>
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<tr>
<td>1</td>
<td>Wernitz, Bickford, Shannahof f-Khalsa 1987</td>
<td>5 Ss</td>
<td>Monitored EEG from occipital, parietal, frontal and temporal lobes Ss were forced to breath through the congested nostril using ipsilateral hand for 11-20 min for one, two or more periods</td>
<td>UFNB through one side produced a relative ↑ in the EEG activity of the contralateral hemisphere This phenomenon is coupled with lateralization of activity in the autonomic nervous system</td>
</tr>
<tr>
<td>2</td>
<td>Shannahof f-Khalsa, Boyle, Buebel 1991</td>
<td>23 Ss (19-30 yr)</td>
<td>Verbal test : modeled from SAT tests Spatial test: Kohs Modified Block Test UFNB was carried while the other nostril was plugged with wet tissue, this was reversed</td>
<td>Right UFNB ↑ verbal efficiency Left UFNB ↑ spatial efficiency Right UFNB ↑ left hemisphere activity and left UFNB ↑ right hemisphere activity</td>
</tr>
<tr>
<td>3</td>
<td>Klien, Pilon, Prosser, Shannahof f-Khalsa 1986</td>
<td>126 Ss</td>
<td>Verbal test and spatial test were assessed while Ss breathed through dominant nostril during spontaneous breathing and also while forcibly breathing through a non-dominant nostril</td>
<td>Verbal performance improved while the right nostril dominant during spontaneous breathing whereas forced nostril breathing had not effect</td>
</tr>
<tr>
<td>4</td>
<td>Jella, Shannahof f-Khalsa 1993</td>
<td>51 Ss (25 males, 26 females)</td>
<td>Verbal tests: modeled after Miller Analogies and SAT test Spatial tests: mental rotation, manipulation and twisting of 2-&amp;3-dimensional stimulus objects</td>
<td>Left UFNB ↑ spatial performance</td>
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</table>
### Studies on general yoga breathing techniques (pranayamas)

<table>
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<tr>
<th>No.</th>
<th>Reference</th>
<th>Subjects &amp; Experience</th>
<th>Techniques Studied and Design of Experiment</th>
<th>Observations</th>
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<tbody>
<tr>
<td>1</td>
<td>Behanan 1937</td>
<td>One Ss, 3 years</td>
<td>Ujjayi, Bhastrika and kapalabhati, Within subject</td>
<td>Oxygen consumption ↑ during Ujjayi, Bhastrika and Kapalabhati by 24.5%, 18.5% and 12% respectively</td>
</tr>
<tr>
<td>2</td>
<td>Miles 1964</td>
<td>One Ss many years</td>
<td>Ujjayi, Bhastrika and kapalabhati, Within subject</td>
<td>Oxygen consumption ↑ during Ujjayi, Bhastrika and Kapalabhati by 32%, 20% and 14% respectively, compared to pre-test values. Post test values showed an ↑ (Ujjayi-5%), and ↓ (Bhastrika, Kapalabhati-3%)</td>
</tr>
<tr>
<td>3</td>
<td>Rao 1963</td>
<td>One Ss many years</td>
<td>Ujjayi at 520m and 3800m altitude Within subjects</td>
<td>During Ujjayi pranayama. Oxygen consumption ↑ by about 7.7%. At higher altitude ↑ by 16.5% more than at lower altitude</td>
</tr>
<tr>
<td>4</td>
<td>Bhargava, Gogate &amp; Mascarenhas 1988</td>
<td>20 Ss</td>
<td>Autonomic responses to breath holding at different phases of respiration Ss practiced 4 weeks nadishodhana Recordings done before and after 4 weeks</td>
<td>Baseline HR and BP (S and D) ↓ and also at breaking point after pranayama breathing This technique appear to alter autonomic responses to breath holding</td>
</tr>
<tr>
<td>5</td>
<td>Telles, Desiraju 1991</td>
<td>10 Ss (28-59 yr)</td>
<td>Oxygen consumption recorded during Long kumbhak and short kumbhak</td>
<td>OC ↑ during short kumbhak (52%) ↓ during long kumbhak (19%)</td>
</tr>
<tr>
<td>6</td>
<td>Telles, Desiraju 1992</td>
<td>One Ss</td>
<td>HR recorded in different types of pranayamas: savitri pranayama (SP), nadi-su-dhi pranayama (NP), mahatyoga pranayama (MP) and vibhaga pranayama (VP)</td>
<td>HR ↑ during VP and MP compared to respective prepranayamic baseline values</td>
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### Studies on uninostril yoga breathing: autonomic functions

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<tr>
<td>1</td>
<td>Telles, Nagarathna, &amp; Nagendra 1994</td>
<td>48 Ss 25-48 yr</td>
<td>Oxygen consumption, Body weight and autonomic measures were recorded. 2 groups : 24 Ss in each group. Group 1: practiced RNYB as 27 respiratory cycles 4 times a day compared with ANYB practiced for the same duration. Group 2: practiced LNYB as 27 respiratory cycles 4 times a day compared with ANYB practiced for the same duration.</td>
<td>OC ↑ in RNYB (37%). Body weight ↓ in RNYB (4.2%) and in NDS (5.1%). HR ↑ in RNYB (6 bpm) also in NDS (4 bpm). GSR ↑ following LNYB (137.7 kilohms). RNYB facilitates sympathetic activity and LNYB facilitates parasympathetic activity.</td>
</tr>
<tr>
<td>2</td>
<td>Telles, Nagarathna, &amp; Nagendra 1996</td>
<td>12 Ss 21-33 yr</td>
<td>Oxygen consumption, Body weight and autonomic measures were recorded. Immediate effect following 45 min practice of RNYB compared with normal breathing.</td>
<td>Following RNYB: ↑ DPV (45.7%). ↑ OC (17%). ↑ Systolic BP (9.4 mmHg). ↓ GSR (60%). RNYB has a sympathetic stimulating effect.</td>
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<td>3</td>
<td>Raghuraj, Nagarathna, Nagendra &amp; Telles 1998</td>
<td>12 Ss 21-33 yr</td>
<td>HRV was measured following Kapalabhati (KPB) and Nadisuddhi (NDS) pranayama.</td>
<td>KPB practice ↑ peak power of LF component (43%) (sympathetic tone), ↓ in HF component (23%) (parasympathetic tone) and ↑ LF/HF ratio (sympathovagal balance). NDS showed a non-significant ↑ in the peak power of HF component.</td>
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| 1   | Stancak & Kuna 1994      | 18 Ss (8 females)     | EEG measured - 28 electrode sites 5 min rest, 10 min inhalation - right nostril, exhalation - left nostril, 5 min rest, 10 min inhalation - left nostril, exhalation - right nostril 5 min rest | Initial period ↑ power of beta 1 (12.1-16.0 Hz) & beta 2 (16.4-30.0 Hz)  
Prolonged period ↑ power of alpha band  
Initial cortical excitation occurs - irrespective of nostril manipulation  
Prolonged practice leads to cortical synchronization |
| 2   | Raghuraj & Telles 2004   | 14 Ss                 | MLAEPs measured from C3-A1, C4-A2, Compared RNYB Vs BAW                                                  | During RNYB ↑ the amplitudes of the Na & Pa waves of MLAEPs on the right side (C4-A2)  
↑ neural activity at mesencephalic-diencephalic level and primary auditory cortex  
RNYB produced ipsilateral changes |
| 3   | Naveen, Nagarathna, Nagendra & Telles | 108 ss (children) | Verbal and spatial memory test Ss divided into 4 groups RNYB, LNYB, ANYB & BAW Practiced 27 rounds 4 times a day for 10 days | ↑ verbal memory scores (84%) in RNYB, LNYB, & ANYB groups  
Did not produced lateralized effects |