

Review

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Review

Know Your Nose: A Narrative Review of Developmental, Functional, Impact, and Importance of Nose and Nasal Breathing on Health and Emotional Wellbeing

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Abstract

This narrative review synthesizes research demonstrating the multifaceted role of nasal breathing in human health and wellbeing across developmental, physiological, immunological, and neuropsychological domains. Nasal breathing emerges as fundamental to infant development, enabling correct breastfeeding mechanics and contributing to proper maxillofacial growth. Nasal structures condition and thermoregulate inhaled air while providing immune defense through nitric oxide production in the paranasal sinuses, mucosal immune barriers, and physical particle filtration. Through nitric oxide, olfaction, and vagal stimulation, nasal breathing influences autonomic and emotion regulation, cognitive performance, and aspects of consciousness. Notably, many traditional spiritual practices, including yogic pranayama, Sufi traditions, and meditative breathing techniques, have long emphasized nasal breathing for physical and psychological wellbeing. Contemporary scientific evidence increasingly validates these ancient practices, revealing how specific breathing patterns enhance parasympathetic tone, increase heart rate variability, and promote physiological and psychological balance. This convergence of traditional wisdom and modern neuroscience affirms the import traditional spiritual practices have long attributed to nasal breathing, with implications for clinical practice, developmental health, and contemplative traditions. Understanding nasal breathing's multifaceted role across these domains can inform interventions that work with the body's natural regulatory mechanisms.

Keywords: nasal breathing; autonomic nervous system; nitric oxide; traditional breathing practices; psychological wellbeing

1. Introduction

Scientific advances in recent decades have shed light on the significance of nasal breathing and the role of the nose (Heck et al., 2019; Tralalon & Schaal, 2012; Zelano et al., 2016). For centuries, nasal breathing has been integral to breathing practices in Eastern cultures such as Buddhism, Hinduism (McAllister, 2020), Kabbalah in Judaism (Zemmelman, 2017), and Tamarkoz in Islamic Sufism (Bahadorani et al., 2021), where it is used to attain higher levels of spiritual consciousness. In recent decades, deep breathing techniques, especially nasal breathing, have garnered attention for their putative impact on stress reduction and relaxation (Zaccaro et al., 2018). These techniques have become almost mainstream in medical communities under the umbrella of alternative and complementary medicine, as well as in mind-body practices in popular culture (Jerath et al., 2015; Kang, 2010).

In the proceeding text, we provide an interdisciplinary discussion of the wide reaching, discipline spanning significance that nasal breathing holds. These topics include evolutionary accounts of the

structure and function of the nose and sinuses and their relevance to nasal breathing; nasal breathing's associations with morphological and autonomic nervous system development; its immunological functions; its role in olfaction; its neurological and psychological effects; its relationship to consciousness; and its place in ancient spiritual practices. Given this breadth and our aim here of educating clinicians on the importance of nasal breathing, we employed narrative review approach.

2. Methods

2.1. Design

This study employed a narrative review approach to synthesize the literature on the neurophysiological mechanisms and health implications of nasal breathing for a clinical audience. Narrative reviews are appropriate when integrating diverse bodies of evidence across multiple disciplines to provide a descriptive analysis and scope of a topic (Ferrari, 2015; Greenhalgh et al., 2018). Given the interdisciplinary nature of this topic, a narrative approach was selected to provide a comprehensive and integrative synthesis.

2.2. Eligibility Criteria

Sources were included if they: (a) addressed physiological, neurological, or psychological influences of nasal breathing; (b) examined developmental aspects of nasal breathing; (c) investigated nasal breathing practices such as pranayama, Tamarkoz, coherent breathing, or other controlled nasal respiration techniques; (d) provided evidence on nasal nitric oxide production and its physiological effects; or (e) examined comparative aspects of nasal versus oral breathing on health and wellbeing. No date restrictions were applied.

2.3. Search Strategy

Literature searches were conducted in PubMed and PubMed Central (PMC) using combinations of the following terms: *nasal breathing, nasal respiration, nasal structure evolution, paranasal sinus function, craniofacial development, olfactory, nitric oxide, vagus nerve, parasympathetic, autonomic nervous system, breastfeeding respiration, infant breathing, pranayama, Tamarkoz, coherent breathing, respiratory sinus arrhythmia, limbic system, amygdala, and emotional regulation*. Reference lists of retrieved articles were reviewed to identify additional relevant sources. The search was not intended to be exhaustive of any single domain; rather, the aim was to synthesize key findings across multiple areas to communicate the importance of nasal breathing to a clinical audience. The first author conducted the searches. The final search was conducted in December 2025.

2.4. Study Selection and Data Extraction

The titles and abstracts were screened for relevance to the above topics. The full text of potentially relevant articles was then judged against the eligibility criteria described above. No formal extraction form was used. Instead, the information was organized thematically according to the article's topic.

2.5. Quality Appraisal

Articles were appraised for relevance to our review's objective rather than formally assessed for methodological quality. However, excepting for the religious texts, all articles included were sourced from peer-reviewed sources, ensuring a baseline standard of scientific rigor.

3. Narrative Synthesis

To provide a more concise analysis, we first review some relevant developmental information. The significance of nasal breathing begins in infancy. In addition to genetic and environmental factors that

play a major role in the development of facial bones and structures such as the maxilla, mandible, teeth organization and alignment (Andriani et al., 2021), nasal breathing during infant's breastfeeding holds a significant role. This function contributes to development and proper growth of sinuses and a well-balanced facial structure (Cudziło et al., 2018). Without meaningful nasal breathing, the infant cannot latch onto the mother's breast correctly (Poskitt, 1988). This act results in creating a vacuum or negative pressure in the mouth, with proper utilization of mouth, tongue, and pharyngeal muscles with their repetitive and coordinated movements, crucial for infant feeding and the development of facial and oral formations and functions (Moral et al., 2010). In addition, Gibson and colleagues (2019) have demonstrated the importance of nasal breathing and breastfeeding in the reduction of the rate of obstructive sleep apnea in the individual's life.

From the first minutes to hours of the infant's life and after all that unpredictable intense rhythmic physical push and uncertainties of natural delivery and birth, the most significant calming and stress-reducing act starts with breast feeding. The multisensory nature of breastfeeding, encompassing touch, warmth, familiar gentle pressure, maternal scent and voice, along with the deeper nasal breathing required for feeding, creates a calming experience second to none (Feldman & Eidelman, 2003).

Nasal breathing during breastfeeding stimulates the sensory mechanoreceptors of vagus and trigeminal nerves in the infant's nasal cavity (Heck et al., 2017). As the result of the rhythmic and repeated act of nasal breathing during suckling, the autonomic nervous system and as part of it the parasympathetic nervous system's tone will enhance. Therefore, stability in heart rate variability (HRV), digestive system function, and emotion regulation take place with more durability (Feldman & Eidelman, 2007). Due to its ancient role in survival, the olfactory bulb, through the olfactory tract, bypasses the relaying and filtering functions of the thalamus and directly connects to the amygdala, enabling rapid survival responses and the formation of powerful emotional memories. Olfactory modification of amygdala activity during breastfeeding reduces stress neurotransmitters and hormones while beneficial hormones and peptides such as oxytocin, endorphins, serotonin, and GABA are released, promoting calmness, bonding, and safety in the infant (Uvnäs-Moberg, 1998; Zelano et al., 2016). With repetition of these processes, the infant's brain establishes strong associative memories faster than at any other time in life, creating permanent and stable neural pathways due to the high synaptic plasticity of infancy (Feldman & Eidelman, 2003).

From an evolutionary standpoint, the structure and shape of the human nose have evolved to enhance olfaction, respiration, safe airway passage, and lung safety, all aimed at maximizing survival, protection, and human well-being (Roseman & Auerbach, 2015). The bony structures of the nasal turbinates have evolved to increase the nasal mucosal surface area and to create airflow turbulence, warming up and humidifying the entering air. Similarly, external structures such as the nostril size and shape may vary among human populations for this purpose. For instance, in colder areas, the nostrils may become narrower to control the flow of cold air and to allow more time for humidification and warming (Kelly et al., 2020). Nasal structures, such as the curve shape of the nose, nostrils, and the coarse hairs in the nasal vestibule, also serve as a first line of defense against pathogens and airborne particles (Zaidi et al., 2017). Paranasal sinuses (sphenoid, ethmoid, frontal, and maxillary) not only reduce the weight of the skull, produce resonance for the voice, and protect the brain from trauma but also contribute significantly to more efficient and healthy breathing (Jankowski et al., 2016). Sinus mucosa trap small particles such as pollen and dust, preventing their entry into the lungs, and contain immune cells and antibodies to guard against potential damage from pathogenic agents such as microorganisms.

Through nitric oxide (NO) production, the sinuses play a notable role in emotion regulation and cognitive function (Maur et al., 2014). NO, a gasotransmitter, is produced by a family of enzymes called nitric oxide synthase (NOS) from the amino acid arginine (Kourosch-Arami et al., 2020).

NOS is found in blood vessel endothelial cells, neurons, and cells participating in inflammatory processes. NO serves diverse physiological functions: it acts as a neuromodulator, serves as an anti-inflammatory agent, and plays a key role in the human immune response and destruction of biological microorganisms (Bauer & Sotníková, 2010). Through its vasodilatory effect, it regulates blood pressure

and contributes to the maintenance of cardiovascular health (Infante et al., 2021). After production in paranasal sinuses, through nasal breathing, NO is directed to the lungs. The degree of NO concentration depends on the continuity and rate of airflow. In an intriguing investigation, researchers compared pulmonary arterial oxygenation between two groups of intubated patients: those deprived of their own nasal NO and those who artificially received their own NO through their ventilator's inhalation limb (Lundberg et al., 1996). In all study subjects, long-term intubated patients who artificially received their own low-dose NO derived from their nose, experienced an 18% increase in their pulmonary artery oxygenation. Moreover, in another arm of the same study, transcutaneous oxygen tension (tcPO₂) in healthy subjects while breathing orally and nasally was measured. It was demonstrated that during nasal breathing, 75% of study subjects had a 10% increase in their tcPO₂, thus increasing oxygen availability to the lungs and cells.

It is postulated that nasal NO may have local and distal influences, such as improvement in pulmonary function by reducing pulmonary artery resistance (Yu et al., 2019) and participation in host defense mechanisms (García-Ortiz & Serrador, 2018). In general, certain microorganisms are destroyed by a concentration of 100 parts per billion (ppb) of NO (Kartal et al., 2010). By comparison, the concentration of NO in nasal airways is several hundred times higher and can reach up to 30,000 ppb in paranasal sinuses (Maniscalco et al., 2016). This is why nasal NO is considered the first line of defense against respiratory particles and microorganisms. This also makes nasal breathing the first line of defense in preventing respiratory infections (Lee et al., 2017).

Some research suggests that NO may protect against coronaviruses. A review by Lisi and colleagues (2021) concluded that in vitro studies demonstrated that NO inhibits the replication of both SARS-CoV and SARS-CoV-2, the viruses responsible for the original SARS epidemic and COVID-19. In another study, using airway epithelial cells Akaberi and colleagues (2020) found that NO inhibited SARS-CoV-2 replication. Clinically, one study reported successful treatment in COVID-19 infected patients using inhaled NO (Zamanian et al., 2020). However, a systematic review found that while NO improved oxygenation, other clinical outcomes including ventilation duration and mortality did not show improvement (Prakash et al., 2021). Thus, the efficacy against the COVID-19 virus appears to be partial and unpredictable, as NO has a complex role in the immunological host responses to viral infections depending on its concentration and the type of pathogen (Lisi et al., 2021). The antimicrobial impact of NO is more widespread against other pathogens (Bath et al., 2021).

Beyond the body's endogenous NO production, specific breathing practices integral to many meditative traditions can substantially enhance these protective and regulatory effects. Humming, for example, may increase NO production up to 15 times more than quiet nasal breathing (Weitzberg & Lundberg, 2002), while breath-holding for 30 seconds after exhalation increases NO concentration and improves nasal obstructions with long-lasting effects (Benedict et al., 2023; Hedhli et al., 2021).

Unilateral nasal breathing such as left or right nostril breathing have consistently shown to increase parasympathetic tone, heart rate variability (HRV), reduce sympathetic activity, and collectively lower stress levels. Due to above impacts, unilateral nasal breathing has gained reputable following (Trivedi et al., 2023; Vanutelli et al., 2024). Although right nasal breathing has been shown to reduce stress perception and relaxation (Vanutelli et al., 2024), left nostril breathing improves sleep quality and reduces hyperarousal (Gajbhiye et al., 2022).

Consistent with this, structural abnormalities which interfere with natural nasal airflow and olfaction function, such as nasal septal deviation, may disrupt sleep, reduce quality of life, and increase rates of depression, anxiety, irritability, interpersonal conflicts, and somatization. Symptom improvements have been observed after surgical procedures restoring normal airflow (Alghamdi et al., 2022). Together, this evidence demonstrates that nasal airflow plays a meaningful role in the balance of the autonomic nervous system via the production and impact of NO, affecting emotional wellbeing, stress resilience, sleep quality, and daily wellbeing.

The nose is filled with bitter taste receptors that not only help with sensory taste and detection of noxious substances but also assist in local immunological responses by detecting the bitter substances created by some bacteria for communicative purposes with each other (Mao et al., 2023). Nasal mucosal

innervation by sympathetic nerve fibers affects local vascular and glandular functions. Nasal gland secretions contain antimicrobial peptides that initiate anti-inflammatory and neurogenic processes using peptides such as histamine and interleukins (Laudien et al., 2011). Secretions absorb inhaled irritants and neutralize microbes or their toxins and potentially facilitate sending informative messages to the central nervous system, thus protecting the respiratory apparatus and enhancing the body's defense against airborne infections (Cole et al., 1999; Kurtz et al., 2004). The sensory information in the nose is detected by chemo and mechanoreceptors. It is reported that each human possesses approximately ten to twenty million chemoreceptors in their olfactory epithelium (Glezer & Malnic, 2019). Chemoreceptors detect and transduce odors, while mechanoreceptors, which are widespread in the nasal mucosa, detect physical or mechanical sensations like pressure, touch, and airflow. The number and function of both receptor types are influenced by different variables, including age, health, genetics, personal habits (smoking or unhealthy living), or professional environments such as those miners and firefighters (McClintock et al., 2020; Sharma et al., 2019).

Olfaction is a primordial sense and its connection to the brain predates the development of the thalamus needed for relaying and filtering the sensory messages for higher order information processing to the neocortex (Shepherd, 2010). It connects to the amygdala and the hippocampus directly through the olfactory bulb found within the skull right above the nasal cavity (Wilson & Sullivan, 2011). Before the dominance of visual and auditory systems, this chemical sense connected vertebrates (humans included) directly to the environment to detect predators through their scent for safety, food for nourishment, and attract mates for procreation, all for survival. Under these critical circumstances, proper usage of every millisecond is invaluable and there is no time for the activation of higher-order, intensive cortical processing. The amygdala must react and activate the hypothalamus and sympathetic nervous system for immediate action in the face of threat (fight or flight) or activate reward system circuitry, including the parasympathetic nervous system, in the face of pleasant and joyful experiences (food or mate), all of which occur outside of conscious awareness (Stevenson, 2010). The visual and auditory systems, with their quantitative fine spatial discriminatory properties, are secondary to the sense of olfaction as a qualitative "good or bad" sense (Rolls, 2004).

It is estimated that only about fifty to seventy percent of odors detected by the nose are consciously recognized. Odors not only impact brain function but also individual's emotional reactions. They regulate mood, cognition, thought content, and behavioral responses consciously and unconsciously (Perciavalle et al., 2017; Syrjänen et al., 2019).

Although the olfactory nerve (cranial nerve I) is the main route for odor transmission to the brain, the trigeminal nerve (cranial nerve V) also conducts signals from air pollutants, irritants, and pungent odors. These include alcohol, ammonia, capsaicin from chili peppers (Libreros-Jiménez et al., 2023), black pepper, mustard, menthol, horseradish, onion, and garlic (Bandell et al., 2004). Pungent chemical compounds, along with temperature and mechanical changes, activate transient receptor potential channels which are ion channels located on the cell surface of trigeminal neurons that transduce a wide range of environmental stimuli modalities, from chemical to mechanical changes (Venkatachalam & Montell, 2007). Stimulation by these agents and their intensity varies between the olfactory and trigeminal nerves. Some like capsaicin have no measurable impact on olfactory nerves and some others such as mustard and menthol have strong impact on trigeminal nerves and a weak effect on olfactory nerve (Rui et al., 2025).

Depending on the type of substrate, these stimulations will reach different cortical and subcortical regions of the brain and generate a variety of emotional, physiological, or behavioral effects (Soudry et al., 2011). Similarly, some substrates may stimulate the vagus or glossopharyngeal nerves (cranial nerves X and IX, respectively), which innervate the larynx or pharynx. They generate autonomic and reflexive reactions impacting breathing or swallowing with potentially deadly reflexive outcomes such as bronchospasm and cardiorespiratory arrest (Sibilla & Agarwal, 2018). Through its direct link to the limbic structures and their vast connections to other segments of the brain, olfactory stimulation asserts its neuro-psycho-physiological impact in extensive parts of the brain (Merrick et al., 2014; Soudry et al., 2011).

Nasal mechanoreceptor stimulation during slow-paced intranasal breathing has been shown to have a modulating impact on thalamic and cortical functions and enabling the alteration of the level of consciousness in humans (Zaccaro et al., 2022). As the relay center of the brain, the thalamus conveys sensory information to the cortex and delivers motor instructions from the cortex to other parts of the brain and body (Cabrera-Álvarez et al., 2023). The thalamus plays a significant role in respiration. It is directly and indirectly connected to the cerebral cortex and limbic system, including the amygdala and hippocampus (Krohn et al., 2023).

Independent of thoracic breathing, animal and human studies have proven the positive impact of nasal breathing on the brain and the autonomic nervous system with calming outcomes (Horii et al., 2013; Jerath et al., 2015). The process is initiated by nose's chemo and mechanoreceptors. This modulating effect originates from the olfactory bulb, which processes electrical signals received from nasal receptors along the nasal pathway (Guyenet, 2014). The connectivity of the olfactory bulb with various brain regions cannot be overstated. Apart from its direct connection to the amygdala, other brain regions and centers are also involved in odor perception, often bypassing our conscious awareness (Nigri et al., 2013).

In a study by Ofer Perl and colleagues, it was found that inhalation during nasal breathing not only activates the brain's olfactory networks but also enhances cognitive and visuospatial task performance, even when unrelated to olfaction (Perl et al., 2019). Furthermore, studies have observed an increase in delta and theta brain waves over the entire cortex and specifically within the Default Mode Network (DMN) during slow olfactory mucosal stimulation (passage of air) (Piarulli et al., 2018). This influence, associated with a reversal in the flow of information from posteroanterior to anteroposterior, correlates with alterations in consciousness levels (Piarulli et al., 2018), allowing practitioners to reach deeper meditative states which have been practiced for thousands of years from Buddhism to Sufism and beyond. The DMN comprises specific brain regions that are active during passive and resting moments such as daydreaming, ruminating, and goal-directed mental activities involving memory recall, episodic memory, or future imagination, and introspection (Menon, 2023). Although the DMN primarily involves the association cortex and para-limbic regions, it does not include the motor and sensory cortices (Mantini et al., 2011). Various practices such as meditation, breath work, and mindfulness can influence the activity of the DMN (Zagkas et al., 2022).

It has been demonstrated that nasal breathing can systematically synchronize the neuronal electrical activity within the piriform (olfactory) cortex and key components of the limbic system, including amygdala, insula, and hippocampus (Zelano et al., 2016). This synchronization manifests itself in a rhythmic pattern and is further pronounced during nasal inhalation while diminishing in mouth breathing.

Additionally, investigations have uncovered that nasal breathing enhances memory retrieval and fear discrimination. As cognitive functions advance, behavioral modification ensues (Heck et al., 2019). Behavioral studies further reveal that nasal respiration modulates the functions of the amygdala and hypothalamus in healthy individuals (Zelano et al., 2016). Beyond its intimate connection to amygdala, nasal breathing influences odor perception mediated by other brain regions and centers (insula, cingula, and olfactory cortex) and impacts our cognitive and emotional landscape to a greater extent, often beyond our conscious awareness (Lübke & Pause, 2015). Another study also has discovered that nasal stimulation (breathing) serves as a significant contributor between the slow breathing, brain and autonomic nervous system, influencing psychological and behavioral outcomes (Riazi et al., 2024).

As part of the limbic system, the insula has a direct connection to the amygdala. It integrates peripheral sensory input, including the sense of smell (Craig, 2002, 2009). It is involved in the subjective experience of smell and human emotional reactions to olfactory experiences (Uddin et al., 2017). Through a process called active interoceptive inference, the brain becomes aware of the body's functional changes to maintain its emotion regulation and homeostasis (Seth & Friston, 2016; Seth et al., 2012). For instance, during stressful circumstances in which feelings of safety due to threat are disturbed, a cascade of events supporting fight and flight is ignited. Heart and breathing rates increase, blood pressure rises, respiration becomes shallow, and a sense of fear and anxiety settles in. As the

individual starts breathing intranasally, intentionally, rhythmically, and slowly, the interoceptive signals become more predictable and a sense of calm and safety returns to the person through this feedback mechanism (Paulus & Stein, 2006, 2010), all mediated by distinct parts of insula and its connections to anterior cingulate cortex, amygdala, hippocampus, hypothalamus, and prefrontal cortex (Barrett & Simmons, 2015; Seth et al., 2012). In this process, the activation of parasympathetic system and production of NO in the nose should not be forgotten.

The anterior cingulate cortex is another limbic region connected to the amygdala and is involved in emotional and cognitive processing of the sense of smell. In general, it regulates emotional reactions, thought modulation, attention, and decision-making (To et al., 2017). The dorsolateral prefrontal cortex also receives information from the olfactory bulb and is involved in executive cognitive functioning, attention, and working memory, as well as evaluating and interpreting olfactory input (Xia et al., 2021).

The spectrum of reactions and behaviors are intensely influenced by the type or intensity of odors and other contributing factors. These may differ from person to person based on individual experiences, familiarity, and other circumstances (Schäfer & Croy, 2024). Secondary to the robust association of olfaction with the previously mentioned brain structures, the nose has a strong impact on the creation of a spectrum of emotional memories and their elicitation (Fokkens, 2021). The robust influence of intranasal breathing on cognition, emotions, and behaviors cannot be ignored.

In an early twentieth-century text, the Sufi Master, Hazrat Mir Ghotbeddin emphasized several practices involving the nasal passages (Ghani, 2024). These include cleansing the paranasal sinuses with clean, cold water as a meditative technique, as well as specific inhalation and exhalation exercises through the nose (Angha, 1956). This unique approach warrants further scientific investigation. In an ongoing project in our lab, application of this technique has demonstrated promising results.

In conclusion, the age-old practice of nasal breathing is deeply ingrained in our individual developmental histories and bears significant importance to our survival. Long before the advent of modern science, nasal breathing was an integral part of spiritual and cultural traditions and began recently to find resonance in contemporary scientific understanding. It transcends its physiological function, influencing various aspects of human health and well-being from infancy to old age. Its profound effects on the respiratory system's health, immune and antibacterial function, cognitive performance, attention, and emotional regulation underscore its significance as a fundamental aspect of human physiology. Its tremendous impact on healthier facial structure development and creation of healthy and secure associative memories and attachment formation is irreplaceable. Embracing this ancient wisdom with modern insights paves the way for a harmonious union of mind, body, and spirit. Breathe in nasally!

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Abbreviations

The following abbreviations are used in this manuscript:

NO Nitric Oxide
NOS Nitric Oxide Synthase
tcPO2 Transcutaneous oxygen tension
ppb Parts per billion
HRV Heart rate variability
DMN Default mode network

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