the Science of Breathing

How you breathe affects how you live; it's more than automatic.

By Sarah Novotny and Len Kravitz, PhD

Breathing techniques and patterns are regularly advocated for relaxation, stress management, control of psychophysiological states and improvement of organ function (Ritz & Roth 2003). Anatomically speaking, there is a favorable equilibrium (balance between inhalation and exhalation pressures) in breathing, which can be easily disrupted by fatigue or prolonged sympathetic (excitatory) nervous system arousal, as seen with stress.

One therapeutic benefit of yoga is that it may reduce or alleviate some of the chronic negative effects of stress (Jerath et al. 2006). This stress relief is one reason that breathing, or **pranayama** as it is called in yoga, is very central to yoga practices.

This article will endeavor to explain the physiological mechanisms and the body-mind connection of breathing and will look at how this connection has been applied to breathing practices, particularly in yoga. Fitness and wellness professionals will become more aware of the effects and benefits of mindful breathing and should be better able to guide and teach their students and clients. Breathing is life, but it's also about quality of life.

Breathing Mechanics 101

Breathing, also called **ventilation,** consists of two phases: inspiration and expiration. During inspiration, the diaphragm and the external intercostal muscles contract. The diaphragm moves downward, increasing the volume of air in the thoracic (chest) cavity, and the external intercostal muscles pull the ribs up and outward, expanding the rib cage and further increasing chest volume. This increase in volume lowers the air pressure in the lungs as compared with the atmospheric air. Because air always flows from a region of high pressure to an area of lower pressure, it travels through the body's conducting airways (nostrils, throat, larynx and trachea) into the alveoli, the microscopic air sacs in the lungs. During a resting expiration, the diaphragm and external intercostal muscles relax, restoring the thoracic cavity to its original (smaller) volume and forcing air out of the lungs into the atmosphere. The practice of proper breathing techniques is aimed at eliminating misused accessory chest muscles and placing more emphasis on diaphragmatic breathing.

Respiration Mechanics 102

While breathing is the movement of air into and out of the thoracic cavity, **respiration** involves the exchange of gases in the lungs. With each breath, air passes through its conducting zone

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into the alveoli. It is here that external (referring to the lungs) respiration occurs.

External respiration is the exchange of oxygen and carbon dioxide between the air and the blood in the lungs. Blood enters the lungs via the pulmonary arteries. It then proceeds through arterioles (small branches of the arteries) into the very tiny alveolar capillaries. Oxygen and carbon dioxide are exchanged between the blood and the air; oxygen is loaded onto the red blood cells, while carbon dioxide is unloaded from them into the air. The oxygenated blood then flows out of the alveolar capillaries, through venules (small veins) and back to the heart via the pulmonary veins. The heart then pumps the blood through the systemic arteries to deliver oxygen throughout the body.

How Does Your Body Control Breathing?

Metabolic Control

The **respiratory center** in the brain stem is responsible for controlling a person's breathing rate. It sends a message to the respiratory muscles, telling them when to contract and when to relax for breathing. The **medulla,** the part of the brain located nearest the spinal cord, directs the spinal cord to maintain breathing, and the **pons** (a part of the brain very near the medulla) provides further smoothing of the respiration pattern. This control is automatic, involuntary and continuous. You do not have to consciously think about it.

The respiratory center knows how to control the breathing rate and depth by the amount (or percent) of carbon dioxide, oxygen and acidosis in the arterial blood (Willmore & Costill 2004). In the arch of the aorta and throughout the arteries, there are receptors, called **chemoreceptors,** that send signals and feedback (to the respiratory center) to increase or decrease the ventilatory output, depending on the condition of these metabolic variables. For example, when you exercise, carbon dioxide levels increase significantly; this alerts the chemoreceptors, which subsequently notify the brain's respiratory center to increase the speed and depth of breathing. This elevated level of respiration rids the body of excess carbon dioxide and supplies the body with more oxygen, which is needed during aerobic exercise.

Upon cessation of the exercise, breathing rate and depth gradually decline until carbon dioxide levels in the arterial blood return to normal. The respiratory center is no longer stimulated from the exercise, and breathing rate is restored to a pre-exercise pattern. This arterial-pressure-regulation feedback system that carbon dioxide, oxygen and blood acid levels provide is referred to as the **metabolic control of breathing** (Gallego, Nsegbe & Durand 2001).

Behavioral Control

Breathing is unique compared with other visceral (e.g., digestive, endocrine, cardiovascular) functions in that it can be regulated voluntarily. The **behavioral, or voluntary, control of breathing** is located in the cortex of the brain and describes that aspect of breathing performed with conscious control—for example, a self-initiated change in breathing before a vigorous exertion or effort. Speaking, singing and playing some instruments (e.g., clarinet, flute, saxophone, trumpet) are good examples of the behavioral control of breathing and are short-lived interventions (Guz 1997).

Behavioral control of breathing also encompasses accommodating changes in breathing that occur as a result of stress and emotional stimuli. The differentiation between voluntary and automatic (metabolic) breathing is that the latter requires no attention, whereas the former involves a given amount of focus (Gallego, Nsegbe & Durand 2001). Gallego and colleagues note that it is not fully understood how the behavioral and metabolic controls of respiration are linked.

Pranayama Breathing

Pranayama breathing is often performed in yoga and meditation. This practice of voluntary breath control refers to inhalation, retention and exhalation performed either quickly or slowly (Jerath et al. 2006). As such, yoga breathing is considered "an intermediary between the mind and body" (Sovik 2000).

In many yoga stories and literature, the word *prana* (in *pranayama*) refers to "life force" or energy. This has many applications, especially as it relates to the energy-producing processes within the body. There is a direct connection between the prana of breathing and its effects on energy liberation in the body. Cellular metabolism (reactions in the cell to produce energy), for example, is regulated by oxygen provided during breathing. The yoga purpose of breath training is not to override or take precedence over the body's autonomic system, although there is clear evidence that pranayama breathing techniques can affect oxygen consumption and metabolism (Jerath et al. 2006). Rather, much of the aim of pranayama breathing is to shift or alter the balance of the autonomic nervous system away from a sympathetic (excitatory) dominance.

Pranayama breathing has been shown to positively affect immune function, hypertension, asthma, imbalances in the autonomic nervous system, and psychological or stress-related disorders (Jerath et al. 2006). Jerath and colleagues add that investigations regarding stress and psychological improvements support evidence that pranayama breathing alters the brain's information processing, making the practice an intervention that improves a person's psychological profile.

Sovik notes that the main philosophy behind the yoga control of breathing is to "increase awareness and understanding of the relationship between cognitive states, physical functioning, and breathing styles." According to Sovik, breath training includes learning to sustain relaxed attention on the flow of breath, to refine and control respiratory movements for optimal breathing, and to integrate awareness and respiratory functioning in order to reduce stress and enhance psychological functioning.

It is interesting also to recognize that there are several types of breathing common to yoga, including the complete yoga breath (conscious breathing in the lower, middle and upper portions of the lungs), interval breathing (in which the duration of inhalation and exhalation are altered), alternate-nostril breathing and belly breathing, to name a few (Collins 1998, Jerath et al. 2006). It is equally worth observing that breath awareness was originally developed in yoga to achieve the joining of mind, body and spirit in the search for self-awareness, health and spiritual growth (Collins 1998). Collins points out that some of the breathing techniques used with yoga postures are complex to learn (for some people) and often require independent practice outside of the postures themselves. Although numerous studies show clinically beneficial health effects of pranayama breathing, some studies show that fast-breathing pranayama can cause hyperventilation, which may hyperactivate the sympathetic nervous system, stressing the body more (Jerath et al. 2006). Thus, some pranayama techniques may be contraindicated for those with asthma because the exercises could lead to agitated bronchial hyperactivity (see "What Is Asthma? Five Common Associated Myths,").

Slow pranayama breathing techniques show the most practical and physiological benefit, yet the underlying mechanism as to how they work is not fully elucidated in the research (Jerath et al. 2006). However, Jerath and colleagues hypothesize that the voluntary, slow, deep breathing of pranayama "functionally resets the autonomic nervous system through stretch-induced inhibitory signals and hyperpolarization currents [slowing electrical action potentials] . . . which synchronizes neural elements in the heart, lungs, limbic system and cortex." Investigations have also demonstrated that slow-breathing pranayama techniques activate the parasympathetic (inhibitory) nervous system, thus slowing down certain physiological processes that may be functioning too fast or conflicting with the homeostasis of the cells (Jerath et al. 2006).

Breath Awareness and Yoga: Making the Connection

In order to maintain breath awareness and to reduce distractions, yoga participants practice pranayama in comfortable postures with eyes closed. An outcome of mastering this breath control is that an individual can voluntarily use the practices to ease stressful or discomfiting situations. Yoga participants learn how to deal with distractions and stress without having an emotionally stimulating physiological response. They practice doing this by first recognizing whatever the distraction or thought may be, and then returning or restoring their focus of attention on their breathing (Sovik 2000). The refocusing centers on the thought, "I am breathing" (Sovik 2000). Yoga enthusiasts also use asanas, or specific postures, with pranayama breathing, linking the movement or body position with the breathing techniques. Jerath et al. (2006) state that more research is needed to understand how combining breathing and asanas elicits beneficial health outcomes.

Answers to Some Common Questions on Breathing

1. How do you take a deep breath?

Although many people feel a deep breath comes solely from expansion of the chest, chest breathing (by itself) is not the best way to take a deep breath. To get a full deep breath, breathe from the diaphragm while simultaneously expanding the chest.

2. What happens when you feel breathless?

Breathlessness is often a response of your "fight or flight" hormone and nervous systems, which trigger the neck and chest muscles to tighten. This makes breathing labored and results in that breathless feeling.

3. What is hyperventilation syndrome?

Hyperventilation syndrome is also known as overbreathing. Breathing too frequently causes this phenomenon. Although it feels like a lack of oxygen, this is not the case at all. Overbreathing causes the body to lose considerable amounts of carbon dioxide. This loss triggers symptoms such as gasping, trembling, choking and the feeling of being smothered. Regrettably, overbreathing is often self-perpetuating, causing carbon dioxide levels to drop even more. Repich (2002) notes that hyperventilation syndrome is common in 10% of the population. Fortunately, slow, deep breathing readily alleviates it. Deliberate, even, deep breaths will facilitate the transition to a diaphragmatic breathing pattern.

4. When you feel short of breath, do you need to breathe faster to get more air?

Just the opposite. If you breathe fast, you may start to overbreathe and lower your carbon dioxide levels. Once again, slow, deep diaphragmatic breathing is recommended.

5. How do you know if you are hyperventilating?

Oftentimes people who are hyperventilating do not realize it. Usually they are focused on the anxiety-provoking situation causing the rapid breathing. With hyperventilation, chest breathing is much more rapid than usual, and thus the chest and shoulders visibly move much more. More quantifiably, if you are taking about 15–17 breaths per minute or more (in a nonexercise situation), you may be hyperventilating.

Source: Adapted from Repich 2002.

What Is Asthma? Five Common Associated Myths

The word *asthma* is derived from a Greek word meaning "to puff or pant." Typical symptoms of asthma include wheezing, shortness of breath, chest tightness and a persistent cough. Asthma attacks develop from an involuntary response to a trigger, such as house dust, pollen, tobacco, smoke, furnace air or animal fur.

Asthma provokes an inflammatory response in the lungs. Airway linings swell up, the smooth muscle surrounding them contracts, and excess mucus is produced. Airflow is now limited, making it hard for oxygen to get through to the alveoli and into the bloodstream. The severity of an asthma attack is determined by how restricted the airways become. When the airways become chronically inflamed, it takes only a slight trigger to cause a major reaction in them. Oxygen levels can become low and even life-threatening.

Below are some of the common myths about asthma.

Myth 1. Asthma is a mental disease.

Because asthma sufferers often have attacks when facing emotional stress, some people have identified it as a psychosomatic condition. Asthma is a real physiological condition. However, emotional stimuli can act as an asthma trigger or worsen an asthma flare-up.

Myth 2. Asthma is not a serious health condition.

Quite the contrary! Asthma attacks may last several minutes or go on for hours. With extended asthma agitation, one's health is increasingly threatened. Indeed, if an airway obstruction becomes severe, the sufferer may experience respiratory failure, leading to fainting and possibly death.

Myth 3. Children will grow out of asthma as they mature to adulthood.

The majority of asthma sufferers will have it for life, although some people do appear to grow out of it.

Myth 4. People with asthma shouldn't exercise.

Asthmatics can and should exercise. They should find the types of exercise they feel most comfortable with, as well as the best place and time to do the exercise.

Myth 5. Not that many people are affected by asthma.

According to the National Center for Health Statistics (2002), 20 million people suffer from asthma in the U.S., and of that number, 4,261 died of it in 2002. Researchers are unclear if this was because of improper preventive care, chronic overuse of asthma medications or a combination of both factors.

Optional Breathing: Activating the Diaphragm

For most untrained individuals, the everyday experience of breathing is much more inconsistent than one would assume. Yoga practitioners often first learn to observe their own breathing to become familiar with the sensations of respiration. Thus, one meaningful aspect of learning breathing techniques is the awareness that develops of the difference between smooth, even breathing and erratic breathing. Modifications in respiratory patterns come naturally to some individuals after one lesson; however, it may take up to 6 months to ultimately change the way one breathes (Sovik 2000). The general rule, noted by Gallego et al. (2001), is that if a voluntary act is repeated, "learning occurs, and the neurophysiological and cognitive processes underpinning its control may change." Gallego et al. go on to assert that longer-term studies are warranted to better understand the attention-demanding phases involved in these breathing changes.

Some yogis believe that the diaphragm, which should play a primary role in respiration, is underfunctioning in many people (Sovik 2000). Thus, emphasis is often placed on learning diaphragmatic breathing, rather than using the overactive chest muscles. Anatomically, the diaphragm sits beneath the lungs and is above the organs of the abdomen (see Figure 1). It lies between the upper (thoracic) and lower (abdominal) cavities of the torso and is attached at the base of the ribs, the spine and the sternum.

With **diaphragmatic breathing,** the initial focus of attention is on the expansion of the abdomen, sometimes referred to as abdominal or belly breathing. The breathing focus includes the expansion of the rib cage during the inhalation.

To help a student learn this, have him or her place the edge of the hands alongside the rib cage (at the level of the sternum); correct diaphragmatic breathing will elicit a noticeable lateral expansion of the rib cage. Diaphragmatic breathing should be practiced in the supine, prone and erect positions, as these are the functional positions of daily life.

Eventually, the diaphragmatic breathing is integrated with physical movements/asanas, during meditation and during relaxation. A trained practitioner can focus attention on daily-life activities while naturally doing diaphragmatic breathing.

Sovik suggests that optimal breathing (at rest) is diaphragmatic, nasal (inhalation and exhalation), smooth, deep, even, quiet and free of pauses.

Pranayama breathing has been shown to positively affect immune function, hypertension, asthma, imbalances of the autonomic nervous system, and psychological or stress-related disorders (Jerath et al. 2006).

Better Breathing for a Better Life

The research is very clear that breathing exercises (e.g., pranayama breathing) can enhance parasympathetic tone (inhibit neural responses), decrease sympathetic (excitatory) nervous activity, improve respiratory and cardiovascular function, decrease the effects of stress and improve physical and mental health (Pal, Velkumary & Madanmohan 2004). Knowledgeable health and fitness professionals may wish to incorporate proper slow-breathing exercises into their sessions and classes as a proven, effective way to help clients and students strive toward their physical and psychological goals.

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References

Collins, C. 1998. Yoga: Intuition, preventive medicine, and treatment. *Journal of Obstetric, Gynecologic, and Neonatal Nursing, 27* (5), 563–68.

Gallego, J., Nsegbe, E. , & Durand, E. 2001. Learning in respiratory control. *Behavior Modification, 25* (4), 495–512.

Guz, A. 1997. Brain, breathing and breathlessness. *Respiration Physiology, 109,* 197–204.

Jerath, R., et al. 2006. Physiology of long pranayamic breathing: Neural respiratory elements may provide a mechanism that explains how slow deep breathing shifts the autonomic nervous system. *Medical Hypotheses, 67,* 566–71.

National Center for Health Statistics. 2002. U.S. Department of Health and Human Services. Centers for Disease Control and Prevention. www.cdc.gov/nchs/products/pubs/pubd/hestats/asthma/asthma.htm; retrieved Nov. 5, 2006.

Pal, G.K., Velkumary, S., & Madanmohan. 2004. Effect of short-term practice of breathing exercises on autonomic functions in normal human volunteers. *Indian Journal of Medical Research, 120,* 115–21.

Repich, D. 2002. Overcoming concerns about breathing. www.conqueranxiety.com/overcoming-concerns-about-breathing.asp; retrieved Nov. 5, 2006.

Ritz, T., & Roth, W.T. 2003. Behavioral interventions in asthma. *Behavior Modification, 27* (5), 710–30.

Sovik, R. 2000. The science of breathing: The yogic view. *Progress in Brain Research, 122* (Chapter 34), 491–505.

Willmore, J., & Costill, D. 2004. *Physiology of Sport and Exercise* (3rd ed.). Champaign, IL: Human Kinetics.