The Science of Breathing by Sarah Novotny and Len Kravitz, Ph.D.

Introduction:

Breathing techniques and patterns are regularly advocated for relaxation, stress management, control of psycho physiological states and to improve organ function (Ritz and Roth, 2003). Anatomically speaking there is a favorable equilibrium (balance in breathing pressures) with breathing, which can be easily disrupted by fatigue or prolonged sympathetic (excitatory) nervous system arousal as seen with stress. This article will endeavor to explain the physiological mechanisms and the mind-body connection of breathing, as well as many of the research driven applications utilized with breathing. Fitness professionals and personal trainers will become more aware of the truths and myths of breathing, and related conditions, so that they can better guide and teach their students and clients.

Breathing Mechanics 101

Breathing, 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 the thoracic (chest) cavity, and the external intercostal muscles pull the ribs up and outward, expanding the rib cage, further increasing this chest volume. This increase of volume lowers the air pressure in the lungs as compared to atmospheric air. Because air always flows from a region of high pressure to an area of lower pressure, it travels in through the body's conducting airway (nostrils, throat, larynx and trachea) into the alveoli of 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. Whereas breathing is involved with the movement of air into and out of the thoracic cavity, respiration involves the exchange of gases in the lungs.

Respiration Mechanics 102

With each breath, air passes through it's conducting zone into the microscopic air sacs in the lunges called 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 and 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, and back to the heart via the pulmonary veins. The heart then pumps the blood throughout the systemic arteries to deliver oxygen throughout the body.

How Does Your Body Control Breathing? **Introducing the Metabolic Control**

The respiratory center in the brainstem is responsible for controlling a person's breathing rate. It sends a message to the respiratory muscles telling them when to breathe. The medulla, 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 and Costill, 2004). There are receptors, called chemoreceptors, in the arch of the aorta and throughout the arteries 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 which alert the chemoreceptors, which subsequently notify the brain's respiratory center to increase the speed and depth of breathing. This elevated respiration rids the body of excess carbon dioxide and supplies the body with more oxygen, which are needed during aerobic exercise. Upon cessation of the exercise, breathing rate and depth gradually declines until carbon dioxide in the arterial blood returns to normal levels; the respiratory center will no longer be activated, 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, and Durand, 2001).

How Does Your Body Control Breathing? **Introducing the Behavioral Control**

Breathing is most unique as compared to other visceral (e.g. digestion, endocrine cardiovascular) functions in that it can also be regulated voluntarily. The behavioral, or voluntary control of breathing is located in the cortex of the brain and describes that aspect of breathing with conscious control, such as a self-initiated change in breathing before a vigorous exertion or effort. Speaking, singing and playing some instruments (e.g. clarinet, flute, saxophone, trumpet, etc.) are good examples of the behavioral control of breathing and are short-lived interventions (Guz, 1997). As well, the behavioral control of breathing encompasses accommodating changes in breathing such as those changes from stress and emotional stimuli. The differentiation between voluntary and automatic (metabolic) breathing is that automatic breathing requires no attention to maintain, whereas voluntary breathing involves a given amount of focus (Gallego, Nsegbe, and Durand, 2001). Gallego and colleagues note that it is not fully understood how the behavioral and metabolic controls of respirations are linked.

Optional Breathing: Activating the Diaphragm

The everyday experiences of breathing for most untrained individuals is much more inconsistent than one would assume. Practices in yoga often first teach individuals to observe their own breathing to ultimately familiarize the student with the sensations of respiration. Thus, one meaningful aspect in learning breathing techniques is the awareness in the difference in smooth, even breathing to erratic breathing. Modifications in respiratory patterns come naturally to some individuals after one lesson, however, it may take up to six months to replace bad habits, and ultimately change the way one breathes (Sovik, 2000). The general rule, often noted in studies, and particularly observed by Gallego et al. (2001) was that if a voluntary act is repeated, "learning occurs, and the neurophysiological and cognitive processes underpinning its control may change." Gallego et al. continue that while some changes can be made, the need for longer-term studies is warranted to better understand the attention demanding phases involved with these breathing changes.

Although the diaphragm is one of the primary organs responsible for respiration, it is believed to be under functioning in many people (Sovik, 2000). Thus, there is often emphasis placed upon diaphragmatic breathing, rather than the use of the overactive chest muscles. Anatomically the diaphragm sits beneath the lungs and is above the organs of the abdomen. It is the separation between cavities of the torso (the upper or thoracic and the lower or abdominal). It is attached at the base of the ribs, the spine, and the sternum. As describe earlier, when the diaphragm contracts the middle fibers, which are formed in a dome shape, descend into the abdomen, causing thoracic volume to increase (and pressure to fall), thus drawing air into the lungs. The practice of proper breathing techniques is aimed at eliminating misused accessory chest muscles, with more emphasis on diaphragmatic breathing.

With diaphragmatic breathing the initial focus of attention is on the expansion of the abdomen, sometimes referred to as abdominal or belly breathing. Have a client place one hand on the abdomen above the navel to feel it being pushed outward during the inhalations. Next, the breathing focus includes the expansion of the rib cage during the inhalation. To help a student learn this, try placing the edge of the hands along side 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. Finally, the diaphragmatic breathing is integrated with physical movements, during meditation and during relaxation. Analogous to the seasoned cyclist, who is able to maintain balance effortlessly while cycling, the trained practitioner in diaphragmatic breathing can focus attention on activities of daily life while naturally doing diaphragmatic breathing. To summarize, Sovik suggests the characteristics of optimal breathing (at rest) are that it is diaphragmatic, nasal (inhalation and exhalation), smooth, deep, even, quiet and free of pauses.

Answers to Some Common Questions on Breathing

The following are some answers to common questions about breathing adapted from Repich (2002).

1) How do you take a deep breath?
Although many people feel a deep breath comes solely from expansion of the chest, chest breathing (in of itself) is not the best way to take a deep breath. To get a full deep breath, learn how to breathe from the diaphragm while simultaneously expanding the chest.

2) What happens when you feel breathless?
Breathlessness is often a response of your flight or fight hormone and nervous system triggering the neck and chest muscles to tighten. This makes breathing labored and gives a person 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. The overbreathing causes the body to lose considerable carbon dioxide. This loss of carbon dioxide triggers symptoms such as gasping, trembling, choking and the feeling of being smothered. Regrettably, overbreathing often perpetuates more overbreathing, lowering carbon dioxide levels more, and thus become a nasty sequence. Repich (2002) notes that this hyperventilation syndrome is common in 10% of the population. Fortunately, slow, deep breathing readily alleviates it. The deliberate, even deep breaths helps to transition the person to a preferable diaphragmatic breathing pattern.

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

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

5) How do you know if you are hyperventilating?

Often times a person does not realize when he/she is hyperventilating. Usually more focus is centered on the anxiety-provoking situation causing the rapid breathing. With hyperventilation there is much more rapid chest breathing, and thus the chest and shoulders will visibly move much more. As well, if you take about 15-17 breaths per minute or more (in a non-exercise situation) then this could be a more quantifiable measure of probable hyperventilating.

Final Thoughts

The research is very clear that breathing exercises can enhance parasympathetic (inhibit neural responses) tone, decrease sympathetic (excitatory) nervous activity, improve respiratory and cardiovascular function, decrease the effects of stress, and improve physical and mental health (Pal, Velkumary, and Madanmohan, 2004). Health and fitness professionals can utilize this knowledge and regularly incorporate proper slow breathing exercises with their students and clients in their classes and training sessions.