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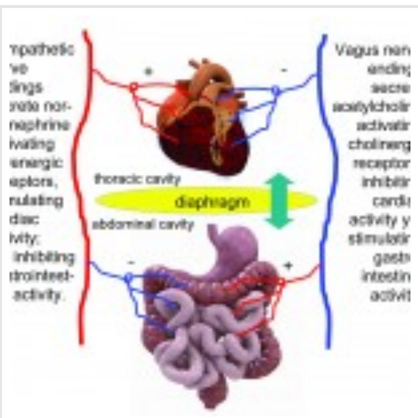
Diaphragm Mediates Action of Autonomic and Enteric Nervous Systems

by **Stephen Elliott** on January 8, 2010 in **Psychophysiology**



The relationship between the diaphragm and corresponding actions of the heart and lungs is well established. In this article, we'll review that relationship as well as explore the diaphragm's little recognized role in abdominal function.

As the diaphragm moves down (inhalation) the volume of the thoracic cavity increases, the pressure in the thoracic cavity becomes more negative, and the lungs fill with air from the conducting airways leading from the nose and mouth and blood from the venous tree and right heart. There, blood and air meet across the extremely thin alveolar surface to effect gas exchange – oxygen for carbon dioxide. During inhalation, heart rate increases to speed filling of the low pressure environment of the lungs via the right heart and to prevent a precipitous fall in arterial pressure while the lungs store a large volume of blood – on the order of 500+ ml.

When the diaphragm moves up (exhalation), the volume of the thoracic cavity decreases, pressure becomes more positive, and the lungs empty of both air and blood. During exhalation, air and blood part ways: air exits the conducting airways, and blood exits the pulmonary vein, where it makes its way to the left atrium, through the left heart, and into the arterial tree, carrying oxygen rich blood throughout the body. Heart rate slows to avoid excessive arterial pressure as the large volume of blood exits the lungs filling the arterial tree. One the venous side, the slowing of the heart rate limits filling of the lungs with blood when they would otherwise be emptying.

Hence, we see an elegant coordination between diaphragm motion and the movement of both blood and air. This process occurs each time we inhale and exhale with depth and regularity. This physiological function is referred to as the "thoracic

Figure 1: Diaphragm separating thoracic and abdominal anatomy

pump" (term as applied here coined by the author), where the action of the thoracic cavity at large facilitates circulation.

The tendency for increasing and decreasing of the heart rate during inhalation and exhalation, respectively, is referred to as "respiratory sinus arrhythmia" (RSA). Principal nervous system functions that mediate this elegant coordination are thought to be those of the autonomic nervous system, more specifically, baroreceptors located throughout major arteries, and cardiac and pulmonary stretch receptors. The increase in heart rate is indicative of a net increase in sympathetic emphasis during inhalation and the decrease in heart rate is indicative of a net increase in parasympathetic emphasis during exhalation. Each time we inhale and exhale with depth and regularity, autonomic status swings from parasympathetic to sympathetic (inhalation) and from sympathetic to parasympathetic (exhalation). In this way the diaphragm is a principal mediator of thoracic status and of *autonomic status at large*.

The diaphragm also mediates activities below it (i.e., those of the abdominal cavity). The clear physical affect that the diaphragm has on abdominal status is easily observed in ourselves where upon inhalation the abdomen protrudes and upon exhalation it sinks. But below the surface of the abdomen what is going on? Surprisingly, though not in retrospect, a like "elegant coordination" exists below as it exists above, but the affect is opposite! Where in the thoracic cavity, as the diaphragm moves down upon inhalation – heart rate speeds up (sympathetic emphasis), and as the diaphragm moves up upon exhalation – heart rate slows down (parasympathetic emphasis). In the abdominal cavity the reverse occurs – neurologically…

The abdomen and its internal organs, principally the gut, is governed by the enteric nervous system, a very complex and sophisticated nervous function of the body. The enteric nervous system has a great deal of autonomy in its action and for this reason it is often referred to as the "gut brain". The enteric nervous system itself is innervated by sympathetic and parasympathetic nerves of the autonomic nervous system which we established above are highly influenced, in effect "regulated", by diaphragmatic action.

Figure 2: Neurologic action is mirror image below vs. above diaphragm.

However, where in the thoracic cavity an increase in sympathetic activity as a consequence of inhalation yields increased activity (i.e., an increase in heart rate), below the diaphragm in the abdominal cavity, the same increase in sympathetic activity yields an inhibitory effect on the enteric nervous system, which slows digestive action (i.e., the secretion of conducting fluids), locomotion, and a myriad of other complex digestive activities. The opposite is also true – whereas in the thoracic cavity an increase in parasympathetic emphasis as a consequence of exhalation results in slowing of the heart rate, in the abdominal cavity, increased parasympathetic emphasis (vagal nerve) stimulates the enteric nervous system which responds by increasing digestive activity.

This opposite action above and below the diaphragm has to do with how sympathetic and parasympathetic nervous signals are interpreted. In the thoracic cavity (above the diaphragm), upon inhalation pressure decreases (becomes more negative) and heart rate accelerates to the net influence of increasing sympathetic action involving increased secretion of nor-epinephrine acting on adrenergic receptors of the heart, and decreasing parasympathetic action involving decreased secretion of acetylcholine serving to deactivate cholinergic receptors of the heart, thereby diminishing vagal inhibitory affect – the net effect is increased heart rate. Below the diaphragm, upon inhalation pressure increases and all of the organs of the abdomen are compressed. The increased secretion of nor-epinephrine that results in activation of adrenergic receptors in the heart, has the opposite effect on the enteric nervous system, inhibiting its action and "slowing" digestion.

The opposite occurs with exhalation. In the thoracic cavity, upon exhalation pressure increases (becomes more positive) and heart rate slows to the net affect of decreasing sympathetic emphasis involving decreased secretion of nor-epinephrine acting on adrenergic receptors and increasing parasympathetic action involving increased secretion of acetylcholine serving to activate cholinergic receptors, thereby increasing vagal inhibitory affect – the net effect being decreased heart rate. Below the diaphragm, upon exhalation pressure decreases and the gut is uncompressed. The decreased secretion of nor-epinephrine that results in slowing of the heart rate has the opposite effect on the enteric nervous system, stimulating its action and speeding digestive processes.

Table 1: Thoracic and abdominal functions mediated by the diaphragm

The elegant coordination of thoracic and abdominal functions is apparent in Table 1. During inhalation heart rate increases and digestive action of the gut slows, and during exhalation heart rate slows and digestive action of the gut increases – a "mirror image" below versus above the diaphragm. Why this arrangement? It is believed that both thoracic and abdominal functions rely on "work" performed by the large thick muscle of the diaphragm where the diaphragm's action literally contributes to the movement of blood through the thoracic cavity and food through the abdominal cavity. This action is summarized in Figure 3 where we can see the effects of inhalation and exhalation on thoracic and abdominal functions.

Stephen Elliott is the principal author of *The New Science of Breath* and *Coherent Breathing – The Definitive Method* and the primary inventor of Valsalva Wave Pro, an instrument that allows observation and training of the respiratory arterial pressure wave.

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About Stephen Elliott

Stephen is the principle author of The New Science of Breath and Coherent Breathing: The Definitive Method. He is an avid heart rate variability researcher and the inventor of the "Coherent Breathing" method as well as "Valsalva Wave Pro" – an instrument that monitors the blood wave in the circulatory system produced during resonant breathing (See www.coherence.com and www.valsalvawave.com, respectively).

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shamtest May 14, 2011 at 5:20 AM #

REPLY

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Christopher Fisher, PhD May 14, 2011 at 12:05 PM #

REPLY

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eric September 30, 2011 at 5:18 PM #

REPLY

Thank you for this well written and informative information.

Christopher Fisher, PhD October 1, 2011 at 8:41 AM #

REPLY

I let Stephen know about your compliment.

Thanks for your readership.

Dr. Fisher

Andy February 27, 2013 at 9:19 AM #

REPLY

What are your thoughts on nasal breathing and slow abdominal breathing (especially whether or not you believe in shallow abdominal breathing or large inhalations into this area)

Christopher Fisher, PhD March 3, 2013 at 9:54 AM #

REPLY

I am not sure what exactly you are asking here. The general breathing style is taught as slow, even, deep, and gentle breathes. Rapid, shallow abdominal breathing mimics anxiety, and I would expect the person to feel more nervous or anxious when engaged in this breathing style. Rapid deep breathes will create hyperventilation or outright panic attacks in those prone to panic attacks.

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