

Slow Breathing

and how it effects our body

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”There are more molecules of air in every breath you take than there are breaths of air in all the atmosphere of the earth.”

-Neil deGrasse Tyson

Pranayama
”trance induced by stopping all
breathing”
(Bhagavad Gītā)

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INTRODUCTION

In order to breath slower it is necessary to find rhythm of breathing that is sustainable for prolonged periods of time. Slow breathing that is followed by involuntary strong inhalation is a sign of either breathing too slow or not having enough volume in each breath. In this essay one learns the basics of slow breathing and how it effects the body. In order to slow ones breathing it is required to practice it regularly in a way that is tiring but not straining.

In slow breathing inhalation and exhalation volumes are bigger than normal daily tidal volumes (see. Minute Ventilation - figure 5. page 10.). If tidal volume is not increased while breathing slower than normally one starts to accumulate CO₂ in the body. Body's natural reaction to this is eventually to increase breathing rate and/or volume.

This essay will cover how breath retention effects the brain and two different reflexes (chemoreflex and baro-reflex) in the body and how they are connected with our breathing and blood pressure regulation.

We take breathing for granted but how does it effect the body and how do different breathing cycles change the functioning of the body? Last part of the essay takes a look into what actually happens during breathing and how altering normal breathing rhythm can change anyones physiology.

ABOUT CO₂

Normally, humans breathe in air that is approximately 20.95% oxygen, 78.09% nitrogen, 0.93% argon, and 0.04% (400 ppm) of carbon dioxide.

Normal breathing

Normal breathing (tidal breathing) is considered as a breathing rhythm that is effortless. Respiration has a relatively constant rate of inspiratory and expiratory volumes (tidal volumes). It is the day-to-day breathing. With normal breathing body tries to maintain certain level of CO₂. At any given moment we have about 2 cubic meters of CO₂ in our bodies.

Biomechanics of breathing

The term “tidal breathing” defines normal respiration with a relatively constant rate and inspiratory/expiratory volumes (tidal volume). Tidal breathing is driven by a group of primary and accessory inspiratory muscles collectively named the “respiratory pump”. The major respiratory muscle is the diaphragm, which, during normal inspiration, contracts and flattens, pushing on the abdomen, while the lower ribs are pushed upwards and outwards [11].

Hypocapnia, also known as hypocapnea

Hypocapnia or hypocapnea (from the Greek words υπό meaning below normal and καπνός kapnós meaning smoke), also known as hypocarbia, sometimes incorrectly called acapnia, is a state of reduced carbon dioxide in the blood. Hypocapnia usually results from deep or rapid breathing, known as hyperventilation. [2]

Excessive breathing creates a low level of carbon dioxide in your blood.

Symptoms that may occur along with hyperventilation

- Numbness or tingling in the fingers
- Lightheadedness
- Pounding heart
- Feeling that air is not getting into the lungs
- Headache

Hypercapnia, also known as hypercarbia

Hypercapnia (from the Greek hyper = "above" or "too much" and kapnzos = "smoke"), also known as hypercarbia and CO₂ retention, is a condition of abnormally elevated carbon dioxide (CO₂) levels in the blood [3].

→ Carbon dioxide may accumulate in any condition that causes hypoventilation, a reduction of alveolar ventilation

Symptoms of increase of CO₂ in the body (Hypercapnia in the blood)

- Blood becomes acidic
- Lowers the blood pH
- Breathing rate and volume increase
- Blood pressure increases
- Heart rate increases
- When combined with water it forms carbonic acid

Symptoms of holding breath to brain

Due to O₂ consumption and a decrease in its partial pressure in the lung alveola, the flowing blood is less and less oxygenated with time. This does not mean that the brain immediately receives less oxygen. Oxygen blood saturation is admittedly lower, yet the blood circulation to the brain is higher, which is caused by the dilation of blood vessels in the brain that occurs with increased CO₂ concentration. [4]

- The arterial oxygen saturation (SaO₂) is reduced with long breath holds, however, the compensatory increase in cerebral blood flow (CBF) could potentially offset the reduced SaO₂ and maintain the cerebral tissue oxygenation. [4]
- Doppler technique for observation of CBF shows the cerebral oxygenation is reduced only slightly until the end of the breath hold at the expense of reduced peripheral blood flow and oxygenation. [4]
- Cranial blood flow (CBF) may potentially compensate for decreased arterial blood O₂ saturation, enabling the body to maintain proper oxygenation of the brain tissues. Intensification of the cranial blood flow is accompanied by the Bohr effect. [4]
- Bohr effect signifies that with high CO₂ concentrations, which occur after a long breath-hold, the blood transfers more O₂ to tissues; and brain tissue in particular is better supplied with O₂. [4]
- With the blood vessels narrowing in the extremities, blood is centralized and results in an increase in blood pressure [5]. Thanks to this effect, the organs that are less vital to the body's survival consume less oxygen because of their lowered glucose metabolism and reduced lactate production [6]. In states of the maximal narrowing of blood vessels (which occur late in the dive and at deep-levels), the extremities are minimally supplied with blood containing O₂, and therefore processes that are maintained during this time are those that are based on anaerobic transformation [7].

After a black out

Over time O₂ reserves are reduced, causing its decrease in the brain. After exceeding a critical state, a brain susceptible to oxygen deficiency cannot function in an anaerobic way and reacts with unconsciousness. Loss of consciousness is a protective reaction, safeguarding the brain from damage. As a result of unconsciousness, all muscles (except the myocardium) stop functioning, which is meant to save any additional oxygen for brain functioning [8]. This protective mechanism helps to avoid brain damage, even in the case of anoxia or the suspension of the heart beat for more than 4 minutes.

WHAT IS CHEMOREFLEX

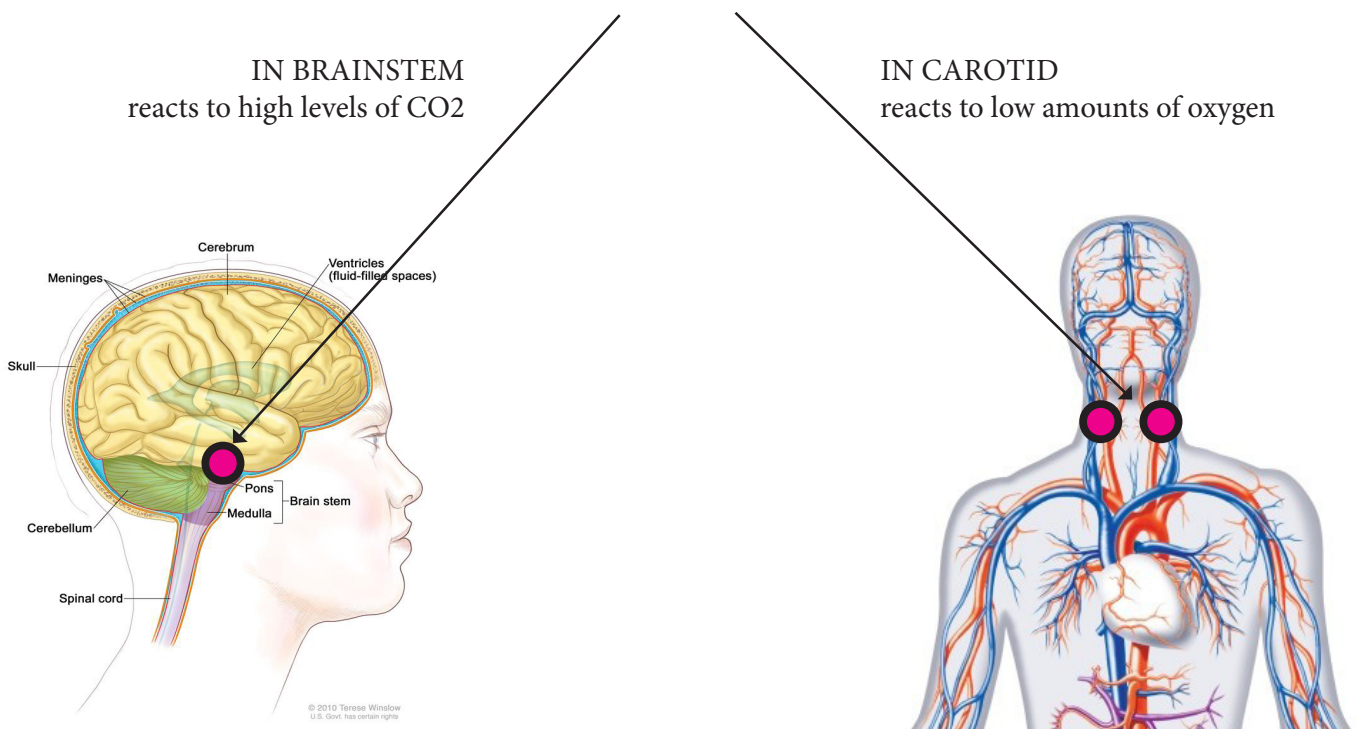
The chemoreflexes are important modulators of sympathetic activation. The peripheral chemoreceptors located in the carotid bodies respond primarily to hypoxaemia. Central chemoreceptors located in the region of the brainstem respond to hypercapnia. Activation of either the hypoxic or hypercapnic chemoreflex elicits both hyperventilation and sympathetic activation. During apnoea, when the inhibitory influence of stretch of the pulmonary afferents is eliminated, there is a potentiation of the sympathetic response to both hypoxia and hypercapnia. [18]

CHEMOREFLEX

The effects of the central and peripheral chemoreceptors on pulmonary ventilation

Chemoreceptors

a sensory cell or organ responsive to chemical stimuli.



BARORECEPTOR REFLEX (BAROREFLEX)

(Baroreceptor, a receptor sensitive to changes in pressure)

- Homeostatic mechanism that helps to maintain blood pressure
- Negative feedback mechanism monitoring arterial blood pressure.
- Responds to acute changes via central-neural-autonomic pathways
- Activated by an increase in blood pressure and fire signals via afferent nerves to the cardiovascular centre in the medulla oblongata
 - This relays fast parasympathetic efferent signals via the vagus nerve to the sinoatrial node to decrease heart rate,
 - Simultaneously sympathetic efferent signals are relayed via the sympathetic chain in the thoracic spinal column to the heart and blood vessels are suppressed, adding to decrease heart rate, cardiac output and vasomotor tone.
- Baroreceptor activity is reduced when blood pressure is low, resulting in the reverse effects. [13]

BREATHING SLOWER

Two ways to breath slower

1. Keep breathing within the tidal volume of your lungs. This will lead to CO₂ build up and after a while one needs to take a bigger and faster breath. This larger breath outside the tidal volume is bodies attempt to restore normal CO₂ levels in the body. It is not possible to breath slower than normally within the tidal volume range for extended periods of time.
2. Breath slowly and inhale and exhale past the normal tidal volume. This additional air in volume allows one to extend each inhalata and exhalation for extended periods of time.

Effects of slower breathing

It has long been known that the heart rate increases during inspiration while arterial blood pressure decreases, and vice versa during expiration [11].

Device-Guided Slow Breathing

On device-guided slow breathing (DGB) studies show a decrease on resting blood pressure in hypertensive patients over periods of weeks [10].

Heart rate variability (HRV)

The autonomic nervous system has a parasympathetic (rest) and a sympathetic (activation) branch. Heart rate variability is an indicator that both branches are functioning – the parasympathetic in particular.

HRV and blood pressure fluctuations shows two significantly correlated rhythmic oscillations. One is at 0.25Hz (High frequency (HF)) and another at around 0.1Hz (low frequency (LF)).

HF coincides with typical respiration frequency (i.e 15 breaths per min, 0.25Hz) is thus connected to tidal respiration on the cardiovascular system.

LF are thought to correspond to cardiac feedback mechanisms that are slower than and independent of respiration [13].

Respiratory Sinus Arrhythmia

Respiratory sinus arrhythmia (RSA) is heart rate variability in synchrony with respiration, by which the R-R interval on an ECG is shortened during inspiration and prolonged during expiration [14].

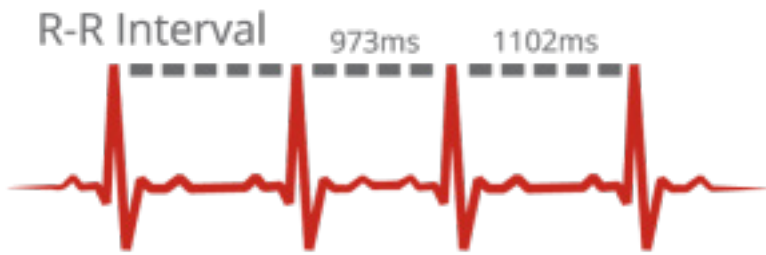


Figure 1. Heart rate variability

- Typically RSA has a frequency of 0.25Hz as seen in the HF HRV oscillation peak. RSA frequency therefore changes with respiration rate [13].
- As respiration rate is reduced, the phase difference is shortened until at the rate of 4 breaths per minute, where HRV and inspiration / expiration were in exact phase. Yet it was at 6 breaths per min (0.1 Hz), where maximization of HRV amplitude was observed (see figure 2).

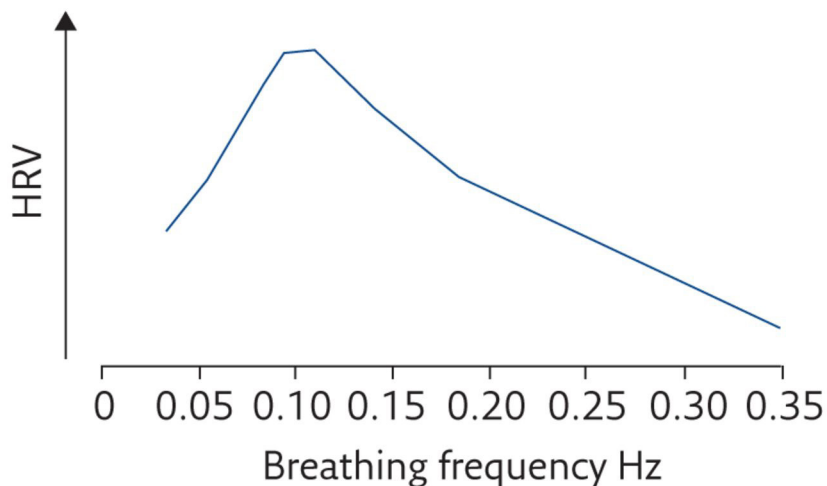


Figure 2. Breathing frequency and it's relation to HRV.

Maximum HRV is typically observed at about a respiratory frequency of 6 breaths per min (0.1 Hz). Reproduced from [12].

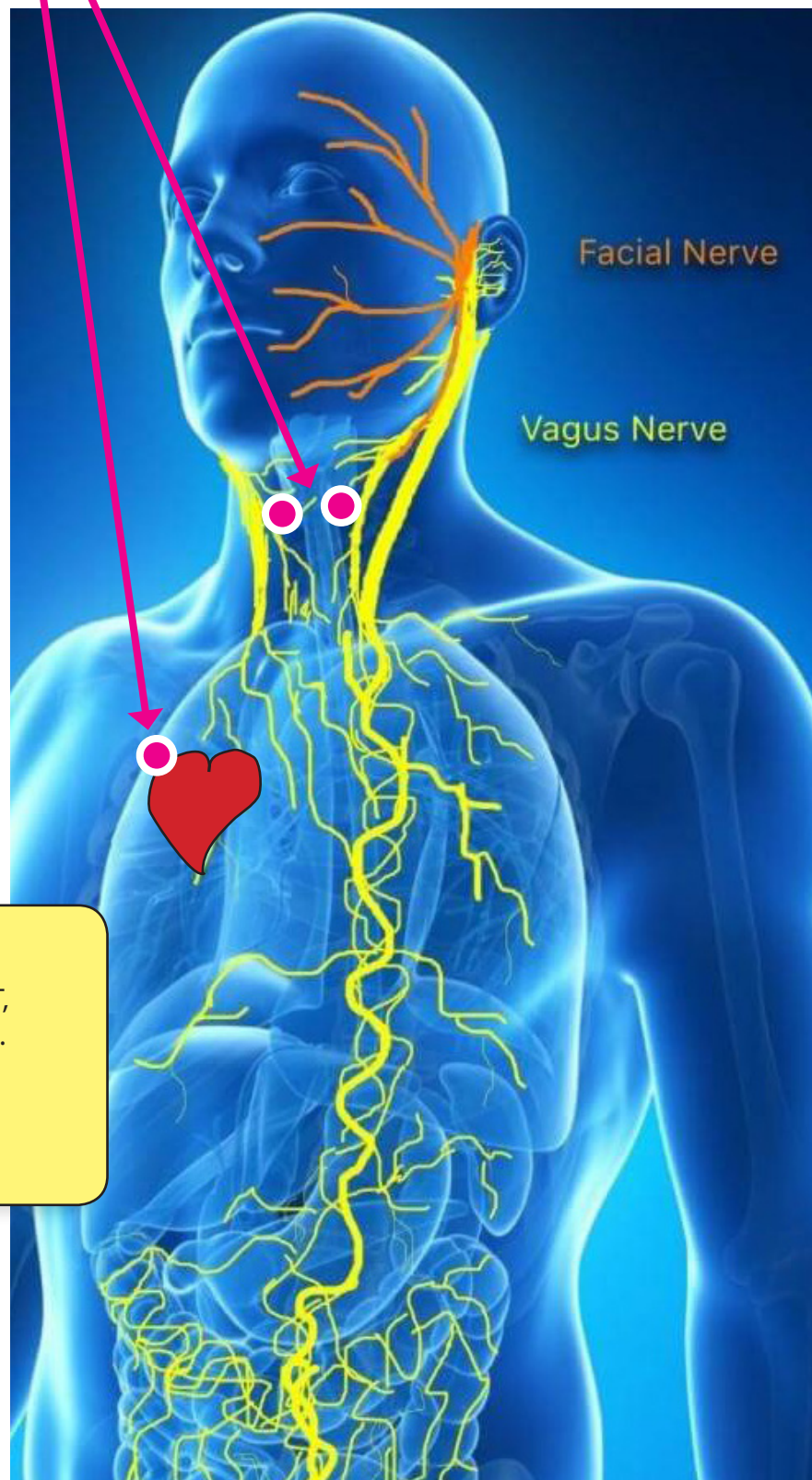
- Maximization of RSA / HRV at around 6 breaths per min has been confirmed by numerous studies [13].

→ “Resonant frequency effect”

- This resonant frequency does vary between individuals. Increasing tidal volume and diaphragmatic breathing have also been shown to significantly increase RSA. Conversely, numerous studies have reported decreased RSA with increasing respiration rate [13].

RSA's significance might lie in it's function to enhance pulmonary gas exchange efficiency by combining cardiovascular oscillation with phases of respiration. By matching ventilation of lungs, heart rate and blood flow would reduce physiological dead space.

RESPIRATORY SINUS ARRHYTHMIA	
Inspiration	Expiration
Diaphragm contracts	Diaphragm relaxes
Chest cavity expands	Chest cavity size decreases
Intra-Thoracic pressure lowers	Intra-thoracic pressure increases
Arterial Blood pressure lowers	Arterial blood pressure increases
-> Deactivates baroreceptors	-> Activates baroreceptors
-> Vagal tone is suppressed	-> Vagal tone not suppressed
-> Heart rate is increased	-> Heart rate decreases



Facial Nerve

Vagus Nerve

VAGUS NERVE

Parasympathetic control of the HEART, LUNGS and DIGESTIVE SYSTEM at rest.

VAGAL TONE

Refers to activity of the vagus nerve.

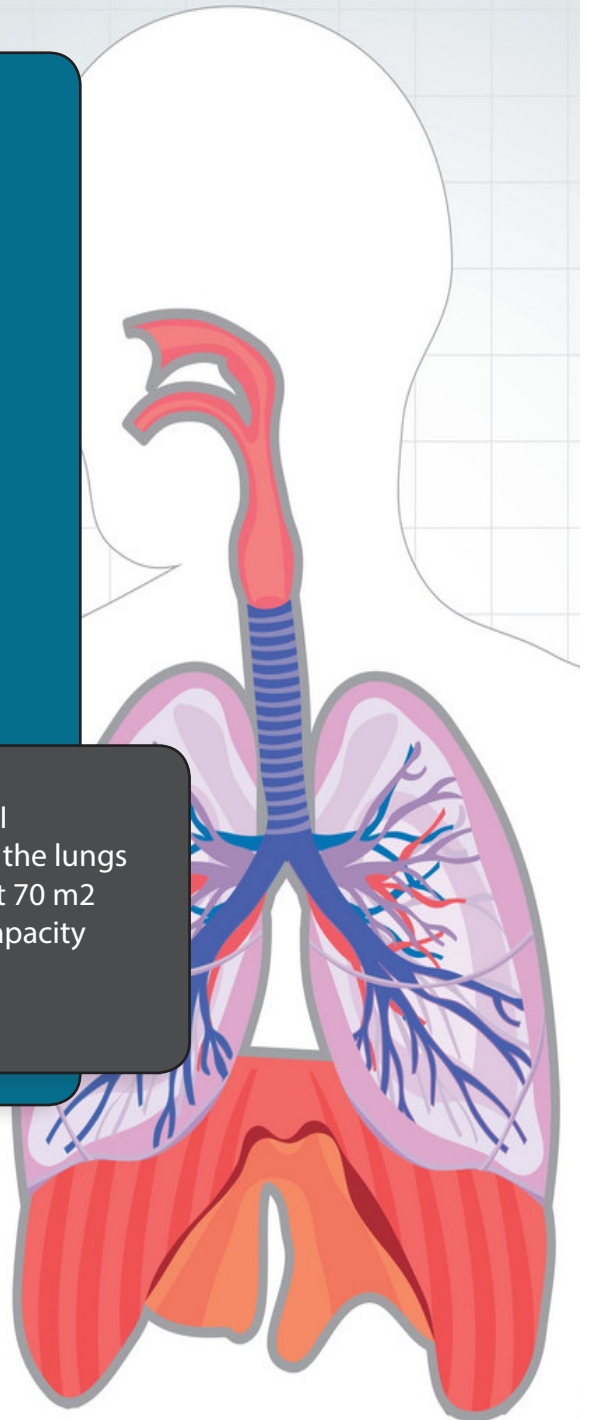
PHYSIOLOGICAL DEAD SPACE

Physiological dead space is the sum of anatomical dead space (air that does not reach the alveoli) and alveolar dead space (air that enters poorly or non-perfused alveoli).

- Increasing respiratory rate does not improve ventilation efficiency because dead space is increased.
- Decreasing respiratory rate and increasing tidal volume has been shown to improve ventilation efficiency.
- 6 breaths per minute was found to be optimal for improving alveolar ventilation and reducing dead space in terms of increased arterial oxygen saturation and ease of sustainability in terms of respiratory effort.
- Also a short hold of breath between breaths can reduce dead space. [15, 16, 17]

QUICK FACTS: ALVEOLI

- 700 million alveoli in the lungs
- Surface area of about 70 m²
- Average total lung capacity
Male: 6 liters
Female: 4 liters



MINUTE VENTILATION

Minute ventilation is defined as respiratory rate multiplied by tidal volume; thus, to maintain minute ventilation, if respiratory rate is decreased, tidal volume must be increased.

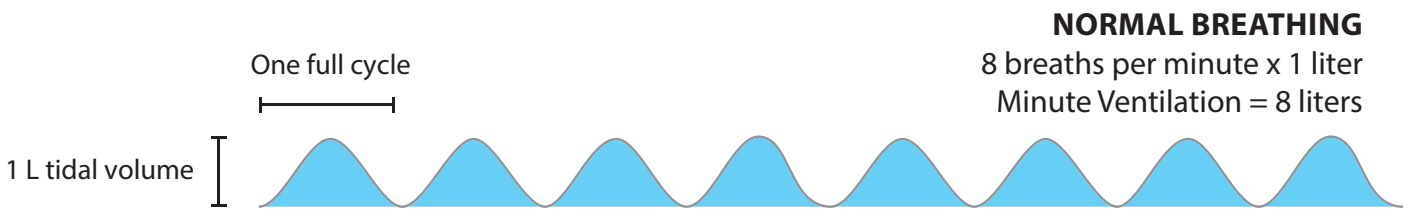


Figure 3. Normal Breathing.

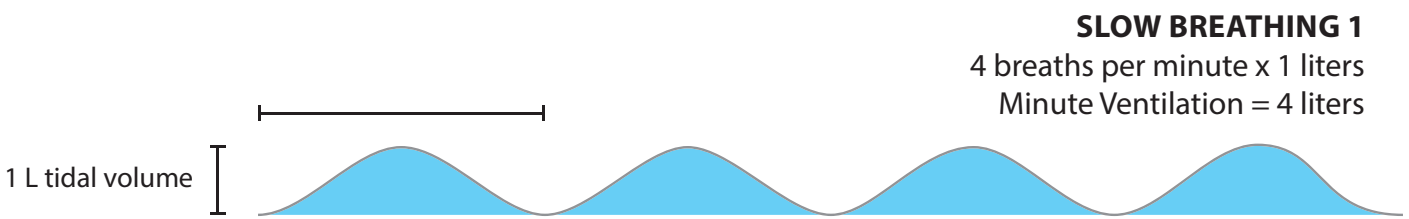


Figure 4. Slow Breathing - 1. Breathing cycle is extended but tidal volume stays the same.

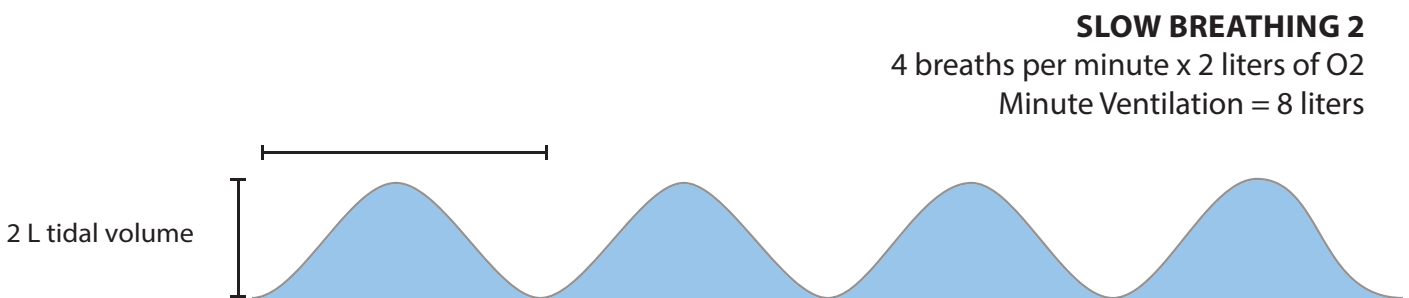


Figure 5. Slow Breathing - 2. Breathing cycle and tidal volume are increased.

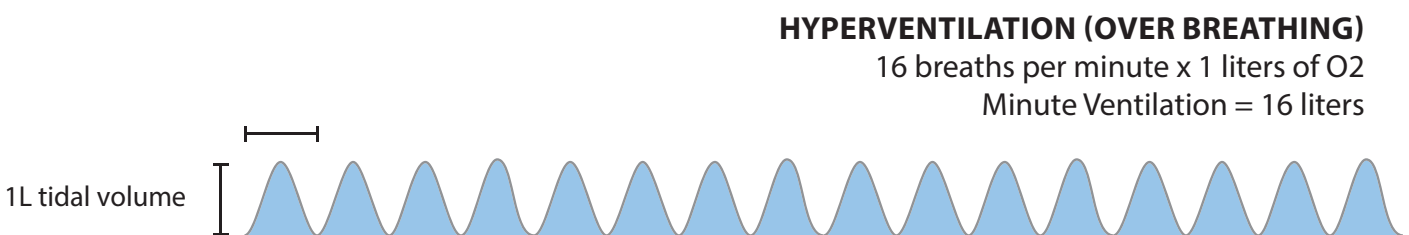


Figure 6. Over Breathing.

A decrease in respiratory rate alone (Figure 4.) would lead to hypercapnia and activation of chemoreceptors (predominantly central chemoreceptors located in the brain stem) that respond primarily by orchestrating a forced increase in respiration rate (hyperventilation) [13]. Therefore, in order to maintain a decreased respiratory rate without disturbing respiratory homeostasis, tidal volume must be increased (Figure 5.). Interestingly, it has been shown that controlled slow respiration at 6 breaths per min in healthy humans reduces the chemoreflex response to hypercapnia and hypoxia, compared with spontaneous respiration (figure 3) or controlled respiration at 15 breaths per min [13].

EXAMPLE ANIMATIONS OF BREATHING

15 Breaths per Minute

http://nestorivirtanen.com/breathworks/RECOVER_test-breath-4.html

6 breaths per minute AND 3 prolonged exhalations per minute

http://nestorivirtanen.com/breathworks/RECOVER_test-breath-3.html

CONCLUSION

All kinds of controlled breathing methods have been part of human culture for thousands of years. It is clear that different ways of breathing have physical effects on us. Modern research brings a more concrete approach to this subject. Certain physiological changes relating to different ways of breathing have been confirmed by multiple studies. The effects of hyperventilation and hypoventilation are known and how slower breathing does lower heart rate and how it can effect our sympathetic and parasympathetic nervous system. Just by observing peoples breathing habits one can see how some breath slower and some faster and how it effects their physical presence.

The aim of this essay was to bring awareness into what happens in the body physiologically. Hopefully this information and examples will help to motivate the reader to pay more attention to ones breathing and work on it.

With consistent Slow Breathing Training one can slow down daily breathing rhythm and decrease any tension in the body. 5 to 15 minute breathing exercises where normal tidal volume is increased and breathing prolonged can change persons breathing habits, in the long run. During these exercises slow breathing becomes tiring, while not being straining. There should not be sudden changes in the breathing rhythm, the breathing should be silent, and tension should be kept to minimum. Think long term with the training. This approach will help to keep the practice enjoyable while enjoying the benefits in the long run. Gaining mastery, breathing included, takes months and years, not days.

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