

Breathing and Yoga

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1. Introduction

The respiration process is responsible to take oxygen (O₂) from the environment into the human body, to use it for the metabolic processes and to return carbon dioxide (CO₂) back to the surroundings. The external respiration is known as ventilation or breathing, the internal respiration refers to the exchange of gases between the blood and the body cells. External and internal respiration are connected by the blood circulation.

Internal respiration is the mechanism that takes oxygen from the blood into the body cells and returns carbon dioxide from the cells to the blood. Almost all the oxygen (approximately 98%) is carried in the blood by attachment to hemoglobin (red blood cells). Carbon dioxide makes far lesser use of hemoglobin but uses other transport mechanism as well.

Here we will deal mainly with the external respiration or the breathing process and will refer to the internal respiration and the blood circulation only in as much as they are helpful to explain conditions of the external respiration.

This article is a modified excerpt from my book Enjoy Hatha Yoga

2. Ventilation – The breathing process

Breathing in is an active process caused by contraction of the respiratory muscles. The diaphragm should do most of the contraction work (75% at rest, see Literature / 1 /, page 20). Due to expansion of the thorax the pressure inside the lungs will fall below atmospheric pressure (757 mmHg vs. 760 mmHg), ambient air will flow via the air passages (nose, throat, trachea, and the more than 20 levels of bronchi and bronchioles) into the alveoli where the gas exchange takes place. At the end of the inhalation the pressure inside the lungs is atmospheric pressure (760 mmHg = 1013 mbar = 101.3 kPa).

Breathing out is a passive process for people at rest, caused by relaxing the respiratory muscles and the elastic recoiling of the lungs and thorax. The volume of the thoracic cavity is decreasing, the pressure inside the lungs exceeds the atmospheric pressure (763 mmHg vs. 760 mmHg) and used air is expelled from the lungs until the pressure inside the lungs equals atmospheric pressure. The out-breath finishes at a respiratory resting level where all respiratory muscles are relaxed.

The absorption of oxygen and the release of carbon dioxide are handled by approx. 300 million to 500 million alveoli (air sacs) in both parts of the lungs. Each alveolus is covered by a fine mesh of blood capillaries. According to different sources in literature, the total area available for the gas exchange in the lungs is in a range from 60 – 140 m².

An increased tidal volume could not only be achieved by deeper inhalation but by forced exhalation as well. That would put the respiratory muscles to work during inhalation as well as during exhalation. More important: While the lung volume and the diameters of the bronchi are increasing when inhaling, forced exhalation decreases both, resulting in higher air flow resistance. Thus forced exhalation requires more effort per extra volume of air than increased inhalation. Therefore it is advised to realize higher tidal volumes by increasing the inhalation, the available inspiratory reserve volume only, and to keep the exhalation passive (this is depicted by the green curve in [Diagram 1](#) on the next page). People unfamiliar with diaphragmatic breathing should practise this form of breathing (see helpful hints in the next chapter) first and increase the tidal volume little by little. Blowing oneself up like a balloon right from the start will cause tension and is counterproductive.

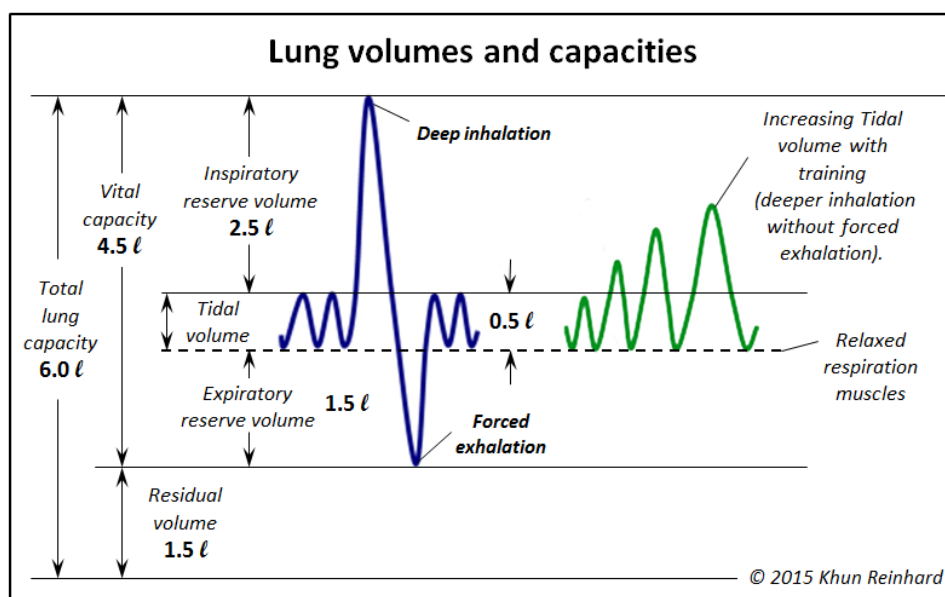


Diagram 1

The lung volumes and capacities as depicted in [Diagram 1](#) are valid for a male adult **at rest** and differ for example with body size and age of the individual as well as with bodily activities. Lung capacities are summarized lung volumes.

- **Tidal volume** – the amount of gas expired per breath (0.5 l).
- **Inspiratory reserve volume** – extra volume of air over and above the tidal volume that can be taken in during a deep breath (2.5 l).
- **Expiratory reserve volume** – volume of air that can be forcefully expelled after a normal expiration by using the respiratory muscles (1.5 l).
- **Vital capacity** – the total volume of air expired after a maximum in- and expiration (4.5 l).
- **Residual volume** – amount of air left in the lungs even after maximum expiration. It can never be forced out of the lungs (1.5 l).
- **Total lung capacity** – the sum of all lung volumes (6.0 l).
- **Dead space** – amount of air that is present in the respiratory tubes where gases exchange does not occur. It is moved with every in- and exhalation without undergoing any change in O₂ and CO₂ concentration (0.15 l). The available gas volume for gases exchange at rest is thus reduced from 0.5 l to 0.35 l.

2.1 Oxygen requirement and breathing frequency

The oxygen requirement per minute of a human being at rest is according to (/ 2 / , page 26) approx.

$$R_{O_2} = k_{O_2} * M_M^{0.75} \quad \text{with: } k_{O_2} = 11 \text{ ml O}_2/\text{min} ; M_M = \text{metabolic body mass in [kg]}$$

For an adult with a body weight of 75 kg the oxygen requirement l per minute would be

$$R_{O_2} = 11 \text{ ml O}_2/\text{min} * 75^{0.75} = \text{approx. } \mathbf{280 \text{ ml O}_2 \text{ per minute.}}$$

350 ml of usable air is inhaled per breath. Ambient air contains 20.9 Vol-% oxygen, exhaled air approximately 16.0 Vol-% (see Table 1 at the end of this text). The body thus uses (20.9-16.0) = 4.9 Vol-%. The oxygen intake per breath is thus

$$V_B = 350 \text{ ml} * (0.209 - 0.16) = \mathbf{17.15 \text{ ml O}_2 \text{ per breath.}}$$

For the number of breaths per minute follows

$$f_B = R_{O_2} / V_B = 280 \text{ ml } O_2 \text{ per minute} / 17.15 \text{ ml } O_2 \text{ per breath} = \mathbf{16.3 \text{ breaths per minute.}}$$

The calculated value of approximately 16 breaths per minute is in line with the observation of many peoples own breathing patterns and with figures given in literature (12 - 16 breaths per minute = 4 - 5 seconds per breath, / 1 / page 24, / 3 / page 153).

Breathing in and out at a rate of 16 breaths/min is quite quick, is already regarded as over-breathing or as hyperventilation by some but this, may be, is the 'normal' rate these days in our busy lives where the body is at rest at times but the mind is hardly ever still.

2.2 The effect of carbon dioxide

When thinking of breathing, people think for good reason of oxygen. But how about carbon dioxide? Carbon dioxide is very important – not only for global warming but for the respiration processes as well.

The carbon dioxide concentration in the blood, characterized by its partial pressure, is one of the determining factors for the breathing process but is also influencing the vascular system, especially the blood circulation in the brain, and the psyche of human beings. An arterial partial pressure of $p_{CO_2} = 40$ mmHg is regarded to be the normal value.

Fewer amounts of carbon dioxide levels can result in stress, anxieties ($p_{CO_2} = 25 - 30$ mmHg, / 6 /), even panic ($p_{CO_2} = 20 - 25$ mmHg, / 6 /) as well as in contracted blood vessels and a resulting lack of blood supply to the body cells. Normal or slightly elevated levels of carbon dioxide are calming and relaxing.

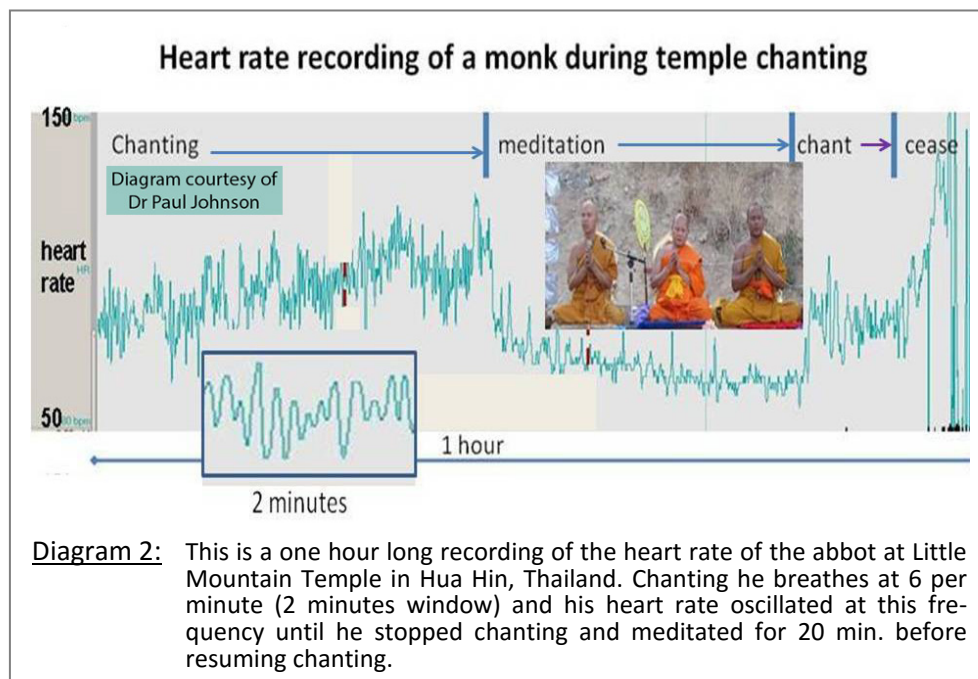
A frequently observed effect of lower than normal carbon dioxide concentration is hyperventilation, usually a quick and shallow form of breathing exuding too much carbon dioxide, pushing the CO_2 -partial pressure below the critical value of $p_{CO_2} = 40$ mmHg. Actually forms of hyperventilation may occur whenever the ventilation is greater than needed. The alveolar gas tensions will then be shift closer to inspired air, ie the CO_2 level will be lower, and the oxygen level a little higher.

As mentioned above, a breathing rate of 16 breaths/min may already be regarded as over-breathing (hyperventilation) with its negative effects on body and mind – a deeper and slower breathing pattern would be desirable.

Slower exhalation helps to empty the lungs completely, thus providing more available space for the following inhalation, which in turn will be slower and steadier as well – the breathing frequency will decrease. Research with chanting and meditating monks by Dr Paul Johnson (/ 7 /, see [Diagram 2](#)) has shown, that the breathing rate under these for both body and mind calming and relaxing circumstances slows down to around 6 breaths/min (see 2 minutes window in [Diagram 2](#)).

It is especially important to slow down the out-breath. By slowing down the out-breath carbon dioxide is kept in the blood at higher levels thus urging an increased oxygen transport from the red blood cells to the tissue, known as 'Bohr-effect' (/ 1 /, page 31), increasing the energy supply of the body. It may sound paradox, but the longer the exhale is extended, the more oxygenation of the body can occur.

And: During breathing-in the sympathetic nervous system, responsible for increased activities and quick response to stress is stimulated, while the out-breath is fueling the parasympathetic system, fostering relaxation. The longer we breathe out compared to the in-breath, the more we can relax.



In yoga it is suggested for ages that we should breathe slowly with the out-breath lasting longer than the in-breath (see the next chapter) and it seems western-scientific methods can now contribute to better understand this ancient recommendation.

Exhaling is usually more than simple muscle relaxation. Controlled, not necessarily forced exhalation is always present when speaking. By the way: Have you ever tried to speak during inhalation? Strain on the body like physical work, many sports and yoga exercises, playing wind instruments and singing are examples of activities requiring forced exhalation. When body and mind are not at rest, breathing parameters will change considerably.

3. Yoga-breathing

Often we breathe shallowly and incompletely, not utilizing the lung capacity. As a result the supply of oxygen is insufficient and the metabolism is impaired. Used air may accumulate in the lung, resulting in feeling tired, indolent, may be even a little depressed. Proper breathing relaxes and has an invigorating effect on the body and the mind, supporting inner balance and peace of mind.

Yoga emphasizes the importance of proper breathing and one of the eight limbs of the yoga of physical and mental control is dedicated to the development and control of breathing, known as Pranayama. In this article a general introduction into the yoga-breathing is given.

Whenever possible breathe in and out through the nose. During practise you can breathe out through the mouth and produce a “pff” tone with the cheeks gently inflated, thus slowing the out-breath. This will support the lengthening of the out-breath towards being approx. twice as long as the in-breath.

The time ratio for breathing should be

2 : 1 : 4

with the 2 being the in-breath,
the 4 being the out-breath
and the 1 being the gap between them.

The above mentioned time ratio of 2 : 1 : 4 is suitable for beginners. With this ratio the breath is flowing smoothly, is not strained. One may start with inhaling for 2 sec., then holding the breath for 1 sec. followed by an out-breath that takes 4 sec. There is no extra gap or break between the out- and in-breath. Little by little one can then increase the times, maybe to 4 (6) sec. – 2 (3) sec. – 8 (12) sec. When practicing Pranayama the ratio will be gradually changed towards longer periods of time for holding the breath like 2 : 8 : 4. Pranayama should be practised only under supervision of an experienced teacher.

When observing the breathing process one can notice that especially the long and slow out-breath will not stop suddenly. It will fade away, almost unnoticeable, becoming gentle and soft and the body ceases to move as the breath comes to an end. One may regard the end of the long and slow out-breath where nothing seems happening as a gap as well.

The ideal breathing is deep, slowly, easy and inaudible. The out-breath should not be intensified or forced. The air should not be retained for longer periods of time as air hunger may shorten the exhalation instead of increasing it. The yogis in India recommend breathing as if we were supplied with a certain number of breaths for our whole life and when this amount is finished we have to die.

The in-breath is active, filling the lungs from the “bottom” to “top” by engaging the respiratory muscles. The out-breath is passive, simply by relaxing these muscles. At first the abdominal area, followed by the chest area, will sink back.

The complete in-breath covers three parts:

1. Abdominal or lower breathing (diaphragmatic breathing), caused by forcing the diaphragm downward, thus making it flat. The belly will be visibly pushed outward. (Approximately 60% share of the total lung capacity).
2. Chest or middle breathing (rib cage breathing), caused by widening the ribs and rising the rib cage. (Approximately 30% share of the total lung capacity).
3. Clavicle or upper breathing (lung tip breathing), caused by rising the upper part of the thorax or by rotating the shoulders forward. (Approximately 10% share of the total lung capacity).

To practise the complete yoga-breathing one can either lie on one's back or sit on a chair. Lying on the back means abdominal and back muscles need not to be tensed to keep the body upright. The muscles necessary for the breathing process can thus work unrestricted.

Breathing exercises in a sitting posture:

- Use a chair or stool with a hard and flat seat. Don't lean against the backrest; sit close to the front end.
- The knees should be below the pelvis. If necessary use a pillow or blanket to raise the pelvis.
- The feet should rest parallel and shoulder width apart on the floor.
- The hands should rest relaxed on the thighs.
- Sitting straight

- Sit with your buttocks on your palms, shift and balance the weight by moving the upper body slightly backwards, forwards and side wards. Sense by the pressure on your hands when you are upright.
- Remove the hands gently one by one, adjust the balance.
- Straighten up from the pelvis to the head.
- Keep the joints relaxed.

Loose and comfortable clothing, fresh air and a relaxed posture are essential.

People with low blood pressure may experience dizziness in the beginning. No need to worry. Lie down and rest the legs higher than the head. The dizziness will disappear. The body will adjust after a couple of days.

3.1 Complete yoga-breathing sequence

Try to visualize the way the breath travels during the breathing exercise.

1. Abdominal (diaphragmatic) breathing

- During practise only: Breathe out completely by pulling the abdomen in and hold the breath for a few seconds.
- Relax the abdominal muscles and breathe in slowly and inaudibly. The abdomen should expand slightly outwards, the chest should not move.
- Place one hand on the abdomen and the other on the ribs to control the movement of the abdomen or the non-movement of the chest respectively.
- The practise of “Tiger breathing” is very helpful if the abdomen will not move in the beginning. You can tighten a belt around your chest to prevent chest breathing.

2. Chest (rib cage) breathing

- During practise only: Breathe out completely by pulling the abdomen in and keeping the abdominal muscles tensed.
- Place the thumbs under the armpits on the sides of the rib cage so the fingertips are touching on top of the sternum.
- Keep the abdominal muscles tensed and breathe in. The thorax widens and the fingertips separate (approximately 3cm if possible).

3. Clavicle (lung tip) breathing

- During practise only: Breathe out completely by pulling the abdomen in and keeping the abdominal muscles tensed.
- Place the right hand under the left collarbone or left hand under the right collar bone and breathe consciously against the weight or slight pressure of the hand.
- Try to pull the collarbones up without lifting the shoulders (rotate the shoulders forward).

4. Complete breathing

- During practise only: Breathe out completely by pulling the abdomen in.
- Place one hand on the abdomen and the other on the ribs to control the movement of abdomen and chest.
- Let the three kinds of breathing follow each other smoothly in the order given above.
- Make sure that after the abdominal breathing is finished and the chest breathing begins, the abdomen does not sink back again, thus filling the chest part of the lungs with air from the lower lungs instead of drawing in fresh air.
- Once you are familiar with the complete breathing sequence it is no longer necessary to control the movements of abdomen and chest with your hands. No more forced exhalation by tensing abdominal muscles.

	Oxygen (O ₂)		Carbon dioxide (CO ₂)		Water (H ₂ O)	Nitrogen (N ₂)
	Fraction	Partial- pressure	Fraction	Partial- pressure	Partial- pressure	Partial- pressure
	Vol-%	mmHg	Vol-%	mmHg	mmHg	mmHg
Ambient air	20,9	158	0,03	0,2	4	597
Alveolus gas	14	104	5,6	40	47	569
Exhaled air	16	114	4,0	29	47	565
Lung vein (to the cells)		100		40	47	573
Lung arteria (from the cells)		40		46	47	573

Table 1: Some components of air and blood and their properties (/ 4 /, / 5 /)

4. Literature

/ 1 / Pulmonary Ventilation

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http://www.breathing-exercises.com/Common_Pitfalls.html

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/ 7 / Dr. Paul Johnson

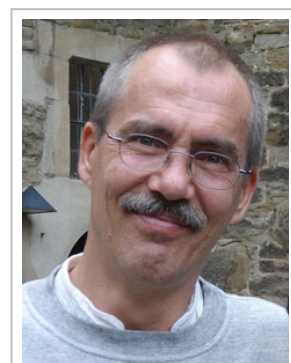
Personal communication

5. About the author

My name is Reinhard Hölscher. In Thailand I'm politely addressed as Khun Reinhard.

For many years now I'm living in southern Thailand, studying Buddhism, practising meditation, teaching yoga and sharing my knowledge and experience regarding both *Theravāda* Buddhism and Hatha-Yoga with a large number of foreign students.

In 1995 I've started to participate in the monthly 10-day meditation retreats at the International Dharma Hermitage of Wat Suan Mokkh, Chaiya, Thailand. First as a participant, then as a helper, yoga teacher and coordinator, and later I've given talks during these retreats. Between 1995 and today I've altogether spent more than seven years at the International Dharma Hermitage.



Khun Reinhard

Together with my wife we are now offering the course 'Introduction to Buddhism and to Buddhist Meditation' at a small meditation centre in Hua Hin (Thailand). Detailed information about this course is available on our website at:

<http://www.meditationinhuahin.org>

Another interest of mine is yoga. I have practised Hatha Yoga for 46 years and taught it for more than 16 years after yoga teacher training in 2000 at the Vivekananda Ashram near Bangalore in India.

During my lessons I have introduced more than 2,000 women and men to the basics of Hatha-Yoga. Most were taught in 10-day courses.

Information, articles and books regarding my meditation and yoga experiences are available on my website at:

<http://www.khunreinhard.com>

Publications

eBooks (available in PDF, EPUP, MOBI ... – format in both English and German language)

- **An Engineer Turned Meditation Teacher - 20 years fascinated by Suan Mokkh –**
- **Introduction to Buddhism and to Buddhist Meditation**
- **Enjoy Hatha Yoga**

Articles (PDF, free of charge, most but not all are available in German language as well)

- **Non-Self and The Five Aggregates**
- **The Here-and-Now-Interpretation of Dependent Origination - An attempt to explain the arising of the self-concept in the human mind -**
- **Karma and Merit in (Thai) Buddhism**
- **Bhikkhuni-ordination controversy in Theravāda Buddhism**
- **Meditation – postures and practices**
- **Meditation in daily life**
- **Aging and Yoga**
- **Breathing and Yoga** **and more ...**