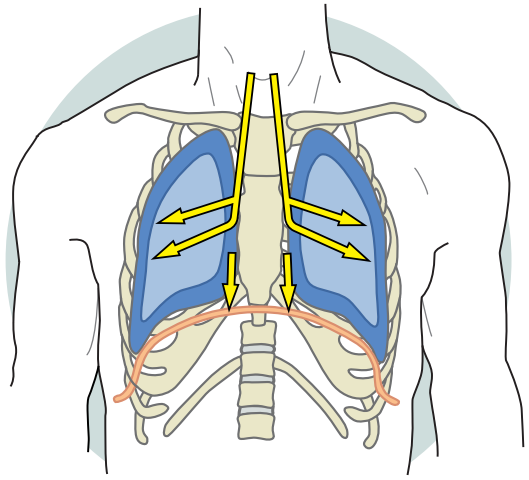
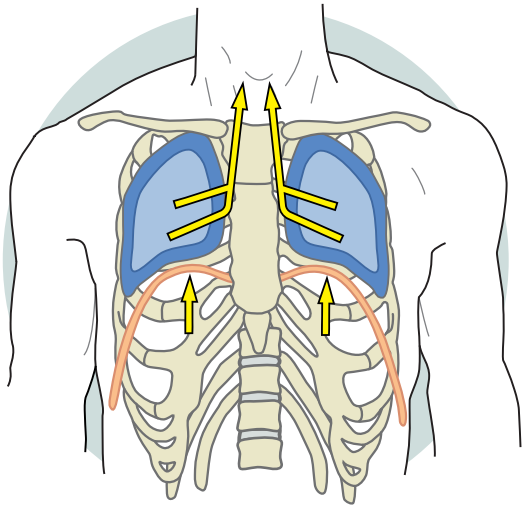
Pranayama (14hrs)

500/1000 Hour Teacher Training | Tiffany Cruikshank and Katja Bartsch



Inspiration



Expiration

Yoga Medicine
Vision & Mission

Vision:

Educate and empower teachers to use yoga therapeutically based on a deeper understanding of anatomy, physiology and the integration of modern science and research with traditional practices and experience.

Mission:

Create an international community of experienced yoga teachers who support the individuals and healthcare systems.

Contents

Three Levels of Respiration, Anatomy of Respiration

Introduction

Oxygen in our atmosphere

- **Great oxygenation event:** explosion of life
- O_2 production from **blue-green algae** through **photosynthesis**
- Today: NASA to develop technologies to oxygenate atmosphere of Mars

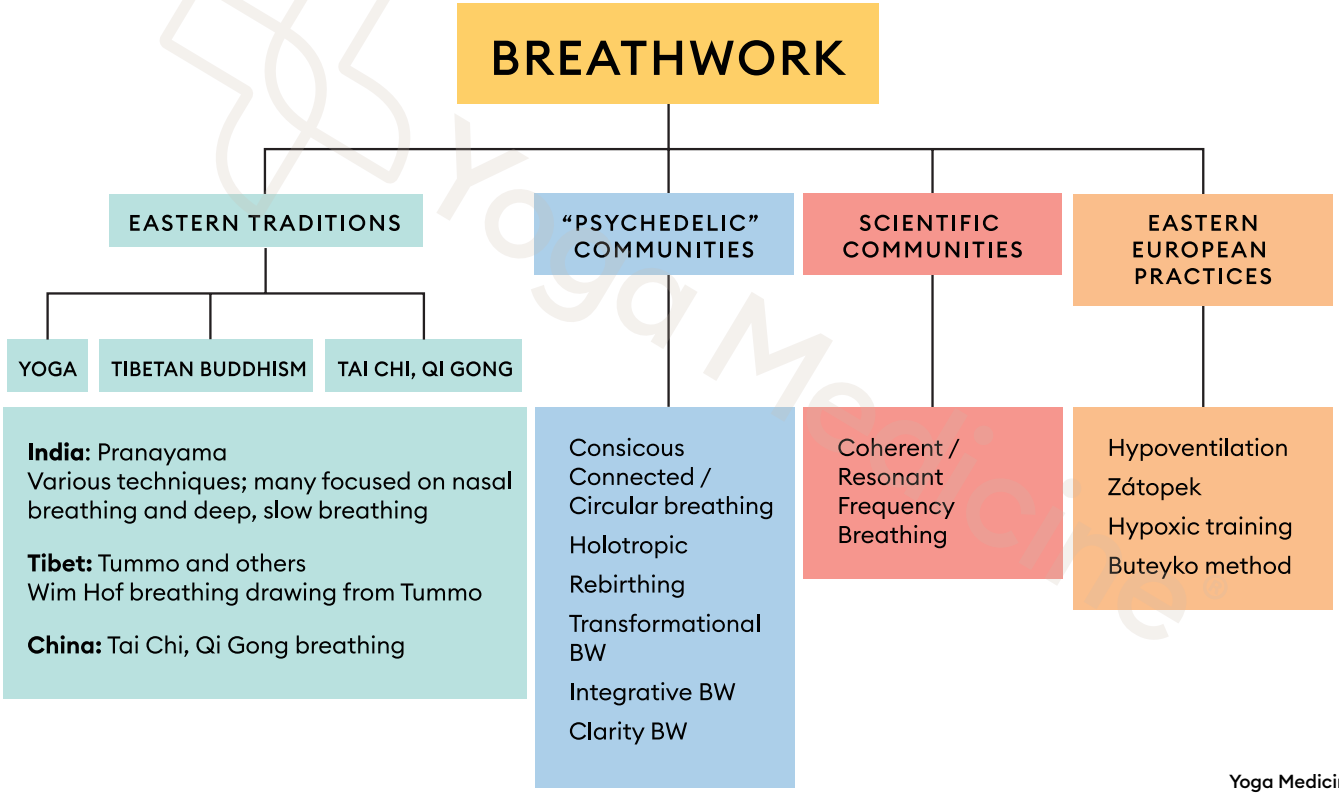
STEPHEN (2021)

Respiration across life forms

- Jellyfish, worms, spiders: no muscular system to increase supply & utilization of O_2
- Fish: able to increase water & O_2 stream into system as needed

STEPHEN (2021)

Breathwork – complex historical roots



Three Levels of Respiration

Ventilation, diffusion & perfusion

- **Ventilation:** movement of air into and out of lungs
- **Diffusion, perfusion:** exchange of O_2 and CO_2 between lungs and blood
- Portion of air stays in upper airways

1 VENTILATION, DIFFUSION & PERFUSION

2 TRANSPORTATION OF BLOOD GASSES

3 CELLULAR RESPIRATION

Transportation of blood gasses

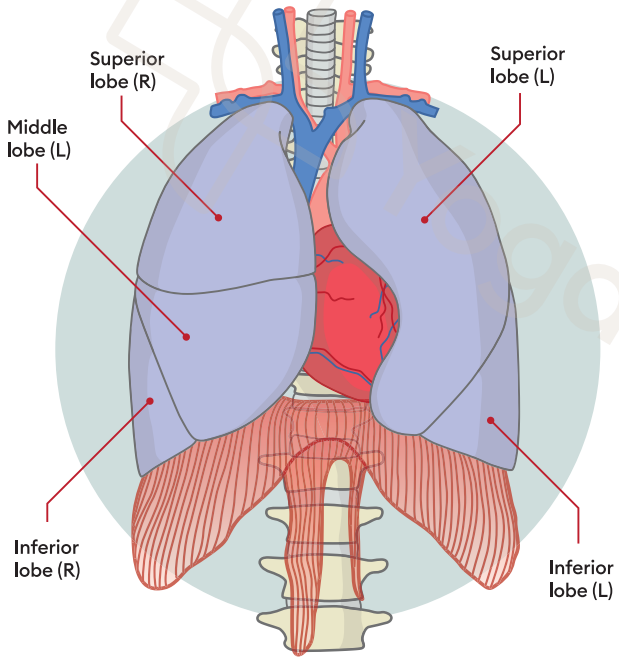
- **Transport** of O_2 and CO_2 via blood
- **Capillary diffusion:** exchange of O_2 and CO_2 between capillary blood and metabolically active tissue

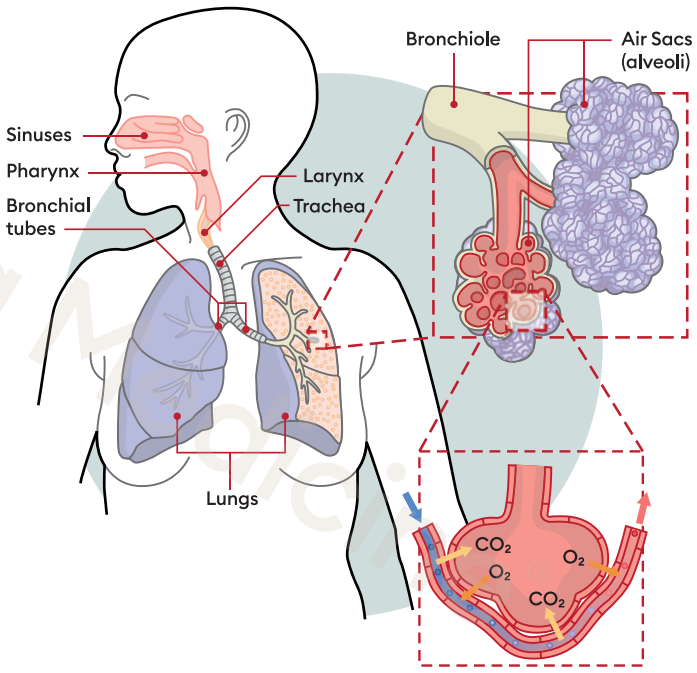
Cellular respiration

- In **mitochondria**
- O_2 needed for **energy production**
- CO_2 diffuses out of cell into blood, returned to the capillaries in lungs and **exhaled**

Anatomy of Respiration

Lungs



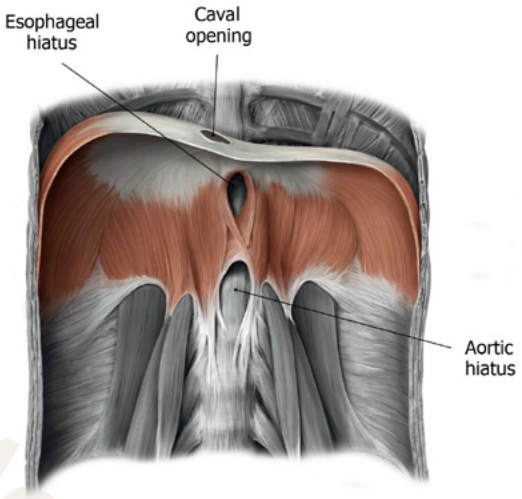


Diaphragm

- Parachute-like dome separates thoracic & abdominal cavities
- Xyphoid/sternum, ribs 7-12, L1 & L2 → central tendon
- Main muscle of inhalation
- Innervation: phrenic nerve
- Connections to: psoas, QL, TVA, pericardium, liver, kidneys, stomach, spleen, pleura of lungs

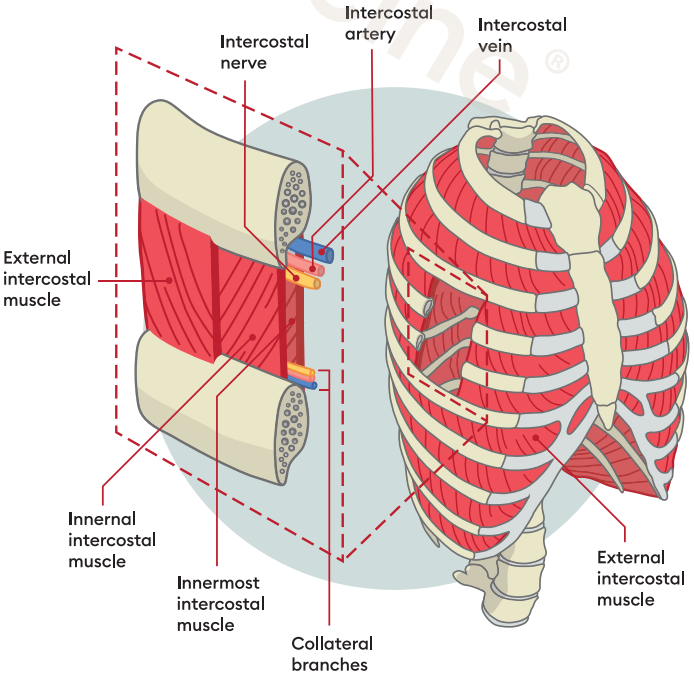
3 openings:

- Esophageal hiatus- vagus nerve
- Caval hiatus- phrenic nerve
- Aortic hiatus- thoracic duct

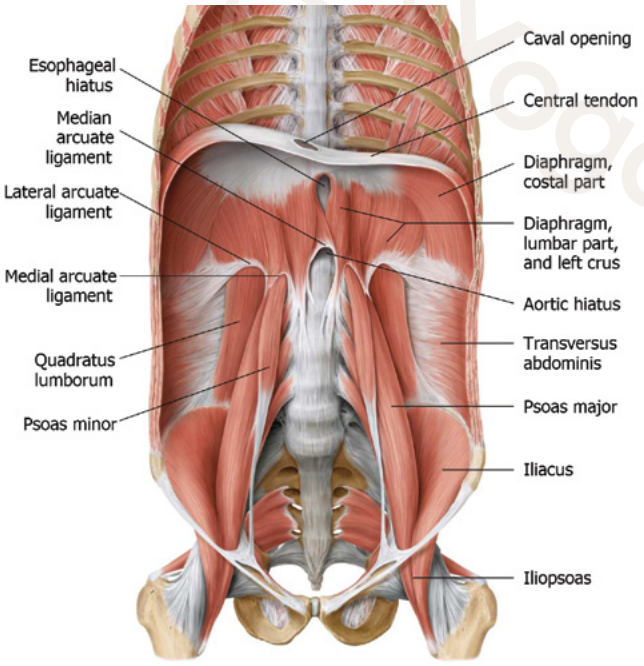


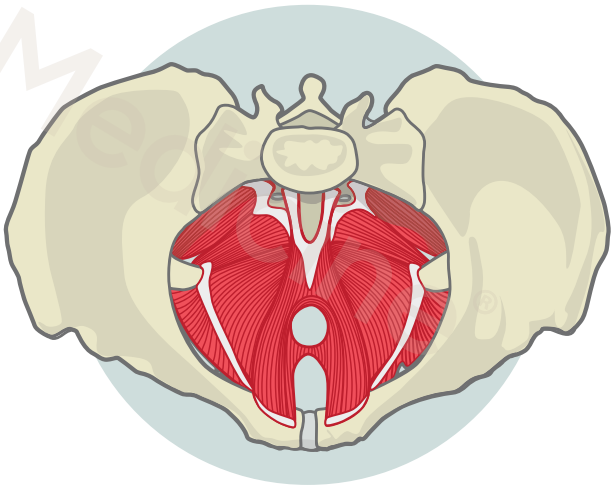
Intercostals

- External: assist inhalation
- Internal: assist exhalation
- Innermost: assist exhalation

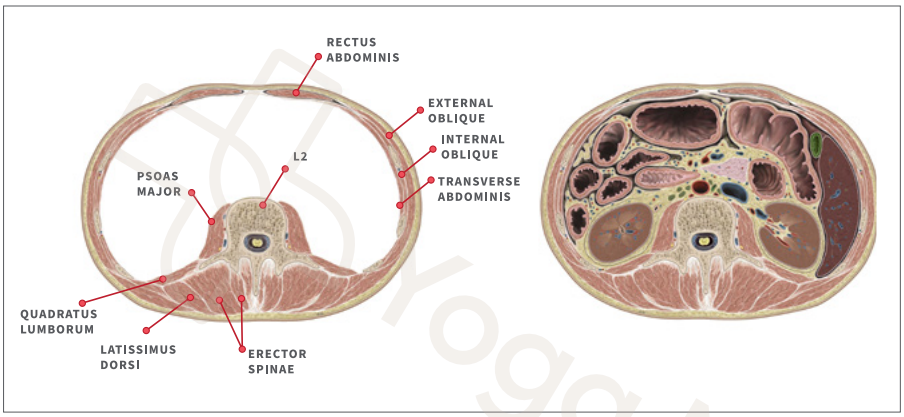


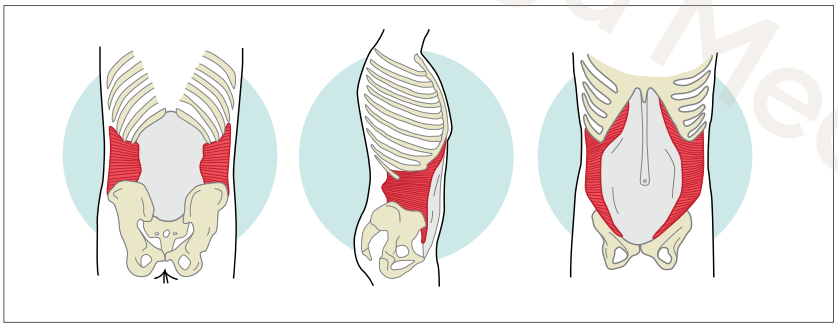
Pelvic Floor, TVA





Pelvic Floor, TVA





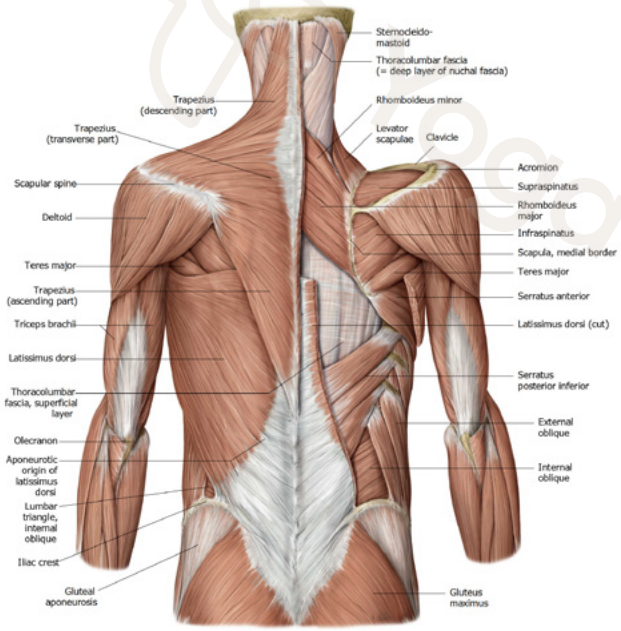
Auxiliary muscles

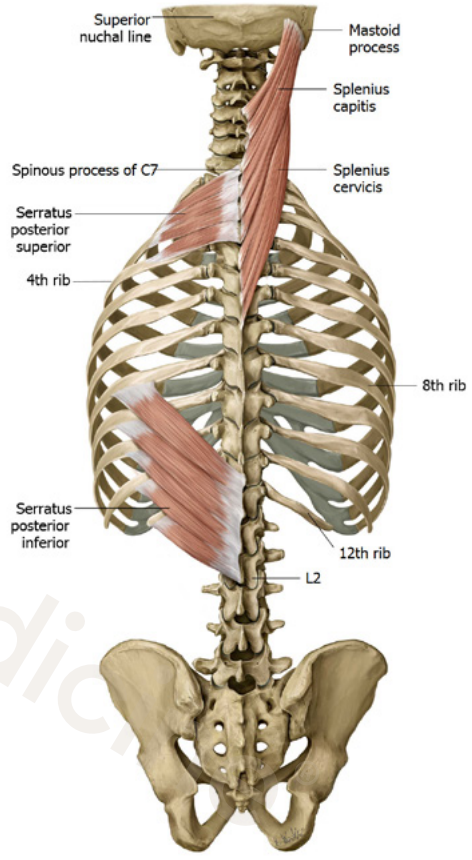
Inhalation:

- SCM, scalenes, pecs, serratus posterior superior, external intercostals, serratus anterior (lats, upper traps)

Exhalation

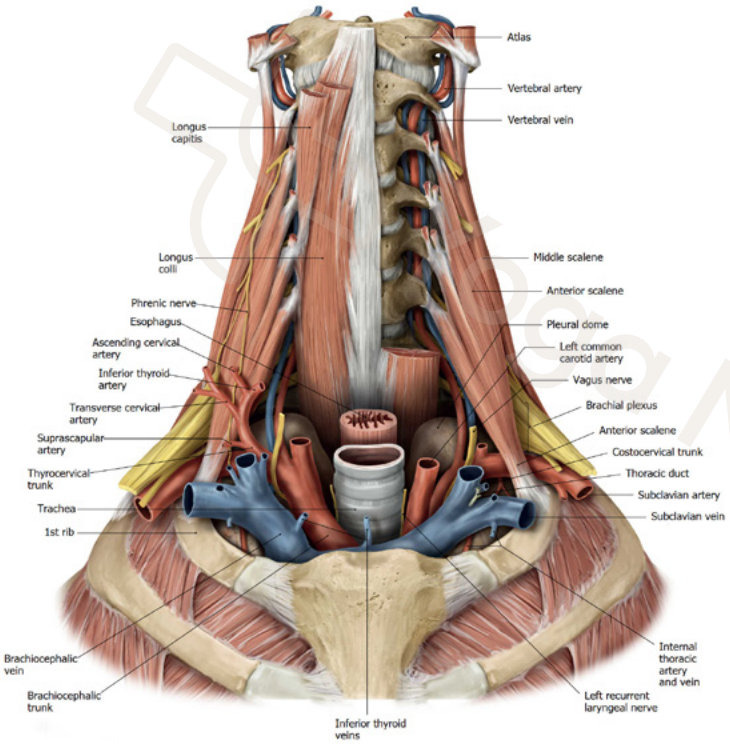
- Internal & innermost intercostals, TVA, internal & external obliques, rectus abdominis, subcostals, serratus posterior inferior

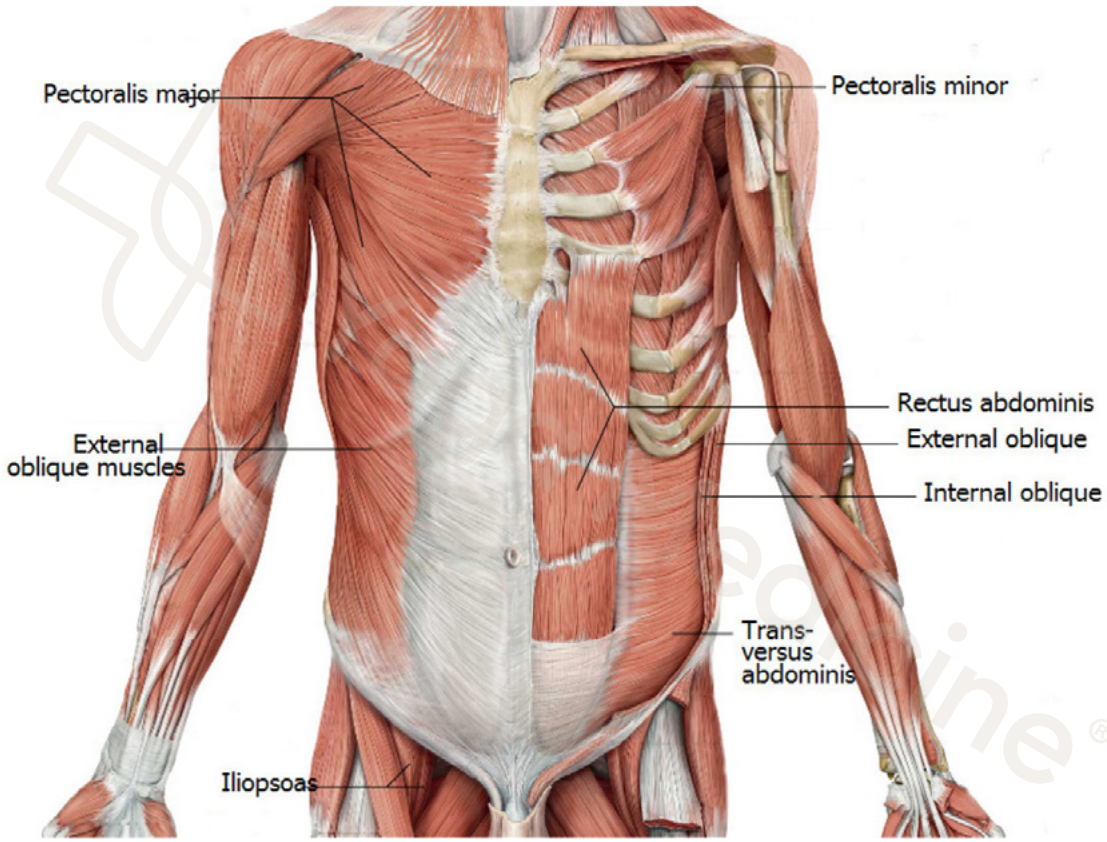




, Fig. 3.10 A, Illustrator: Wesker/Voll,

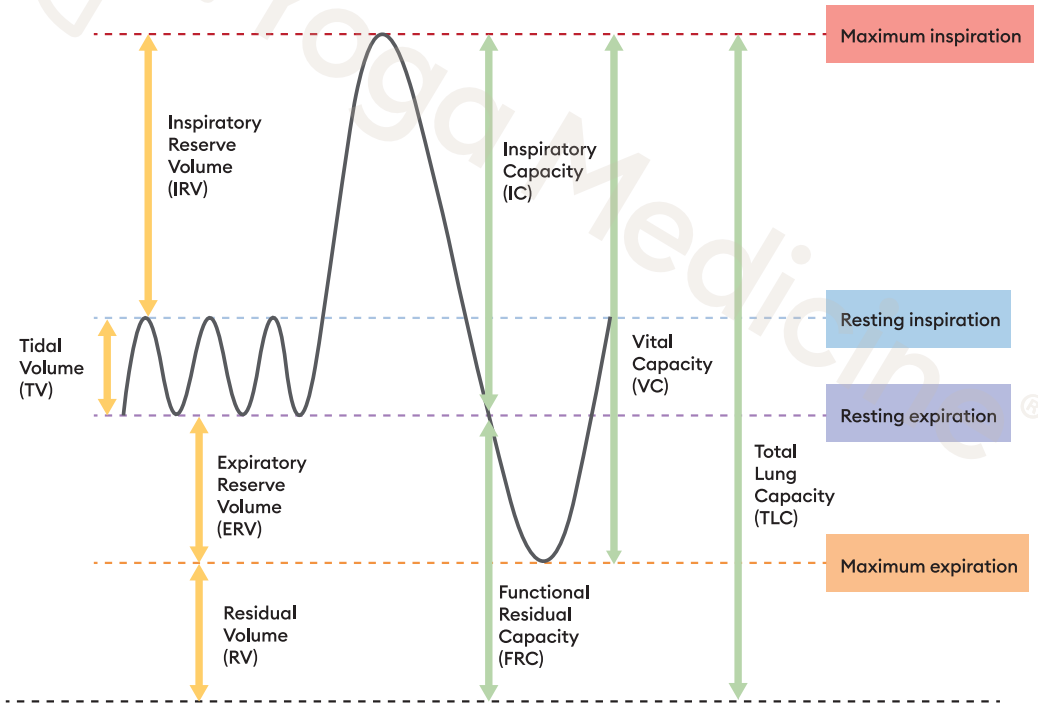
Auxiliary muscles





Breathing Mechanics

Lung volumes and capacities



SOURCE: LUFTI, 2017

BENNETT & ZEMAN, 2005; CASALE ET AL., 2007; KAHANA-ZWEIG ET AL., 2016; LUFTI, 2017; SWIFT ET AL., 1988

Types of ventilation

- **Minute ventilation: volume x frequency**
- **Dead space**
  - » **Anatomical:** filling conducting zones
  - » **Physiologic dead space:** anatomic + alveolar dead space
- **Alveolar ventilation:**
  - » Relevant for effectiveness of ventilation

APPLICATION	
	Shallow, rapid breathing (e.g. 35 breaths/min) would almost exclusively make use of dead space ventilation with only minor gas exchange in alveoli
	Deepening breath increases alveolar ventilation (via alveolar recruitment and distension).

BILO ET AL., 2012; RUSSO ET AL., 2017

How does exercise change lung function?

- Total lung capacity reflects **genetic influences & body size characteristics**
- Exercise can enhance strength, endurance of breathing muscles
  - » **Ventilation** can be increased
  - » Helps to **load, transport and utilize O_2**

BIERSTEKER & BIERSTEKER 1985; MCARDLE ET AL., 2010

Pathways: Nasal breathing

- Nasal cavity: **higher resistance to expiration** than mouth
- **Variability among ethnic groups**
- Nasal cycle:
  - » **Wake vs. sleep:** switches every ~ 2 hours / ~ 4.5 hours
  - » **Speed of breathing:** bigger difference in slow breathing
  - » **Posture:** side-lying

BENNETT & ZEMAN, 2005; CASALE ET AL., 2007; KAHANA-ZWEIG ET AL., 2016; SWIFT ET AL., 1988

Pathways: Mouth & pursed lips breathing

Mouth breathing:

- » During higher demand for air
- » Can deliver larger volumes of O_2 at faster rate

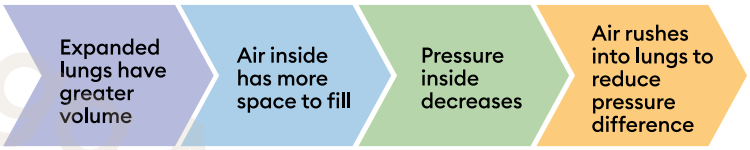
Pursed lips breathing:

- » Resistance through constriction of lips
- » Slower & deeper breathing patterns
- » Increased abdominal expiratory muscle recruitment at rest

JEFFERSON, 2010; NIINIMAA ET AL., 1980; RECINTO ET AL., 2017; SPAHIJA ET AL., 2005

Inhalation – at rest

- **Active inhale**, passive exhale
- **Diaphragm contracts downward**
- **Ribs raise** (help of external intercostals)



BENDIT, 2019: PATEL ET AL., 2022; WELCH ET AL., 2019

Inhalation

- **Abdominal muscles** indirectly help
- Can be **further assisted by auxiliary breathing muscles**
- **Dysfunctional breathing pattern (upper-thoracic dominant breathing)**
  - » Ribs and belly hardly expand
  - » Dominant upper thoracic & neck area
  - » More shallow & faster breath

PATEL ET AL., 2022

Rib motion: pump & bucket handle

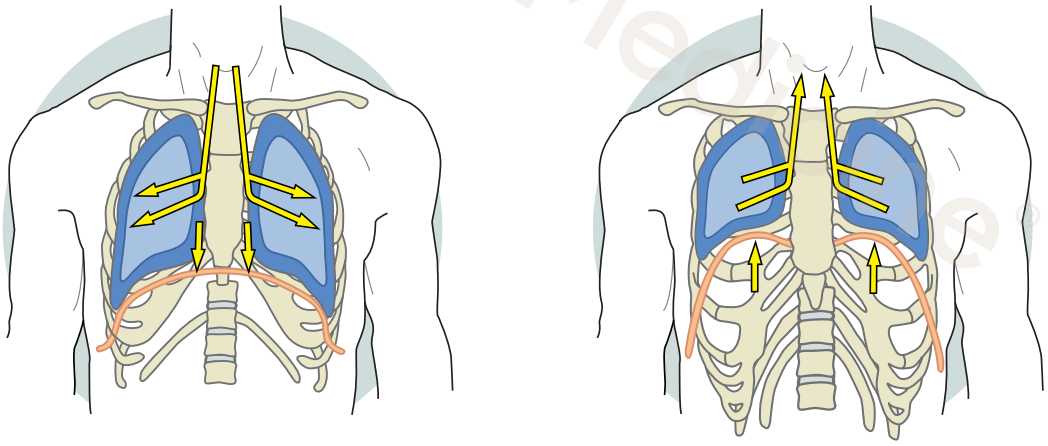
Pump-handle motion

- Ribs move out and up to front
- Primarily 1st - 6th ribs
- Sternum lifts
- SCM and scalenes

Bucket-handle motion

- Side ribs move out and to the side
- Primarily 7th – 10th ribs
- Increasing transverse span of ribs
- Diaphragm and external intercostals

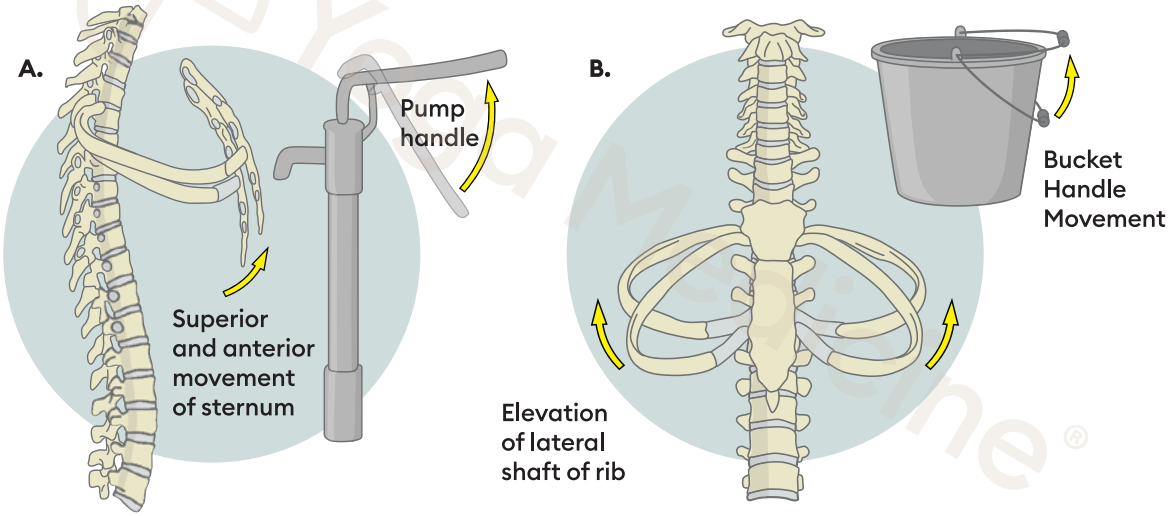
Diaphragm movement



Inspiration

Expiration

Rib and diaphragm movement



Sex differences in breathing mechanics

Males:

- Pyramidal lung geometry → greater diaphragmatic action on lower lungs

Males: predominant bucket-handle rib movement

Females:

- Smaller lung capacity & ribcage, greater rib inclination
- Prismatic lung shape → increased intercostal muscle action, affecting upper lungs
- During exercise: more auxiliary muscle recruitment in females, lesser diaphragmatic fatigue

Females: predominant pump-handle rib movement

BELLEMARE ET AL., 2003; DOMINELLI & MOLGAT-SEON, 2022; MITCHEL ET AL., 2017; TORRES-TAMAYO ET AL., 2018

Exhalation – at rest

- At rest, exhalation is **passive**
- Natural **recoil** of diaphragm, lung tissues, chest wall
- **Relaxation** of inspiratory muscles

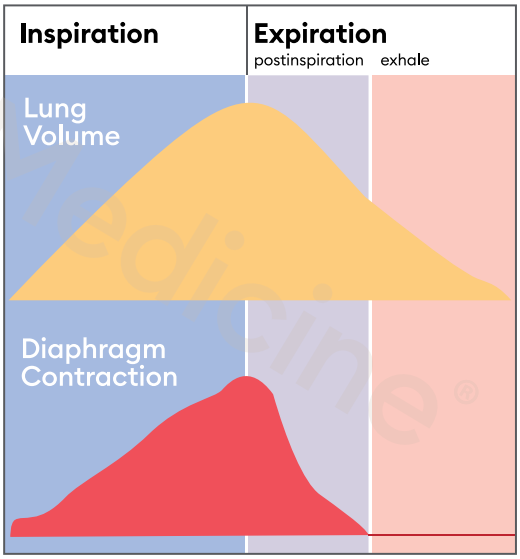
Exhalation – active expiration

- With greater demand, expiration transforms from passive to **active**
- Supported by muscles that **depress thorax and reduce its size**
  - » Air moves more quickly out of lungs

ASHHAD ET AL., 2022

Postinspiration

- Part of **expiration**
- **Slows** expiratory airflow
- Maximizes **time for gas exchange**
- Laryngeal adductors: resistance to counteract recoil force of lung & chest wall
- Eccentric activation of diaphragm prevents its abrupt relaxation



ASHHAD ET AL., 2022; BELLINGHAM, 1998; DEL NEGRO ET AL., 2018; DUTSCHMANN ET AL., 2014

Breathing disorders

Obstructive	Restrictive
Reduction in air flow	Reduction in lung volume
Difficulty getting air out	Difficulty getting air in
Often coupled with prolonged exhalation time, pursed lip breathing	May go along with rapid, shallow upper chest breathing
Examples: • Asthma • COPD (chronic obstructive pulmonary disease)	Examples: • Acute inflammation • Pulmonary fibrosis • Neuromuscular cause

Breathing disorders - asthma

Research on pranayama & asthma

- Most studies include different breathing techniques
- Improvements include: lung function, systolic BP, pulse rate, QoL

APPLICATION	
	**Bhastrika, kapalabhati:** exercise respiratory muscles → potential improvements in pulmonary function
	Making full use of diaphragm & abdominals in breathing may help in removal of secretions

ANSHU ET AL., 2022; BHATT & RAMPALLIVAR ET AL., 2016; JAYAWARDENA ET AL., 2020; SANTINO ET AL., 2020; SAXENA & SAXENA, 2009; SUBG ET AL., 1990; SODHI ET AL, 2014; SODHI ET AL., 2009

Respiratory (thoracic) pump

Pressure decrease in thoracic cavity

- Diaphragm descends → thoracic cavity expands → thoracic pressure decreases
- Impact on heart wall → right atrial pressure lowers → facilitates venous return

Pressure increase in abdominal cavity

- Abdominal pressure increases when diaphragm descends

Inferior vena cava passes through thoracic AND abdominal cavity

- Thoracic pressure decrease + abdominal pressure increase squeeze blood up towards heart

Effects of posture on breathing

- **Seated:** increased **rib basket** contribution
- **Seated with back support:** greater contribution of **abdomen**
- **Supine:** increased **abdominal** contribution
- **Side-lying**: pre-stretch of top side

From which position you teach Pranayama, matters.

ROMEI ET AL., 2010

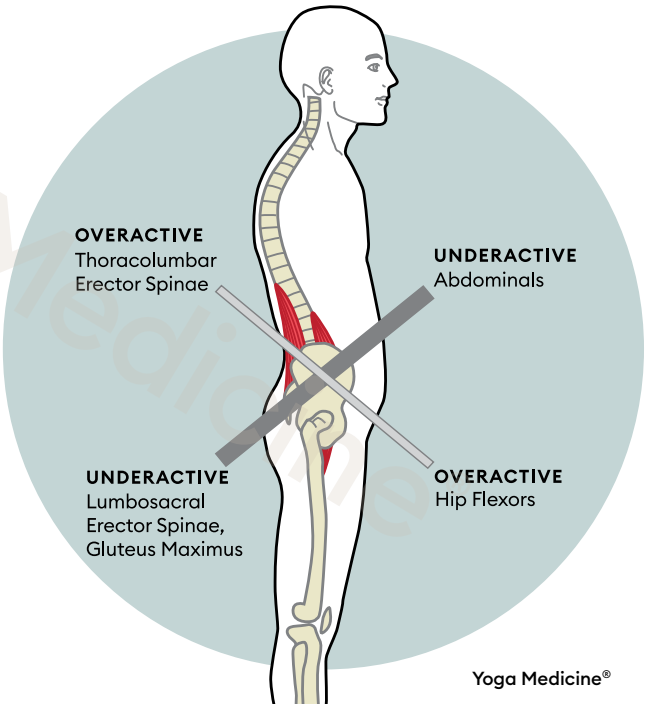
Posture & breathing – therapeutic considerations

Breathing exercises can help to alter spinal curve.	• Respiratory training straightened thoracic hyperkyphosis. • Repetitive deep breathing resolved stiffness of rib basket; straightened thoracic kyphosis
Spinal dimensions may predict pulmonary function.	• Distance between T1 and T12 predicted pulmonary function in early-onset scoliosis patients.
Spinal stability may be compromised during increased respiratory demand.	• Diaphragm involved in postural stability control during sudden voluntary limb movements • Reduced contribution of diaphragm and TVA to postural control in hypercapnea

GLOTBECKER ET AL., 2014; HODGES ET AL., 1997; HODGES ET AL., 2001; IZUMIZAKI ET AL., 2006; OBAYASHI ET AL., 2012

Posterior pelvic crossed pattern

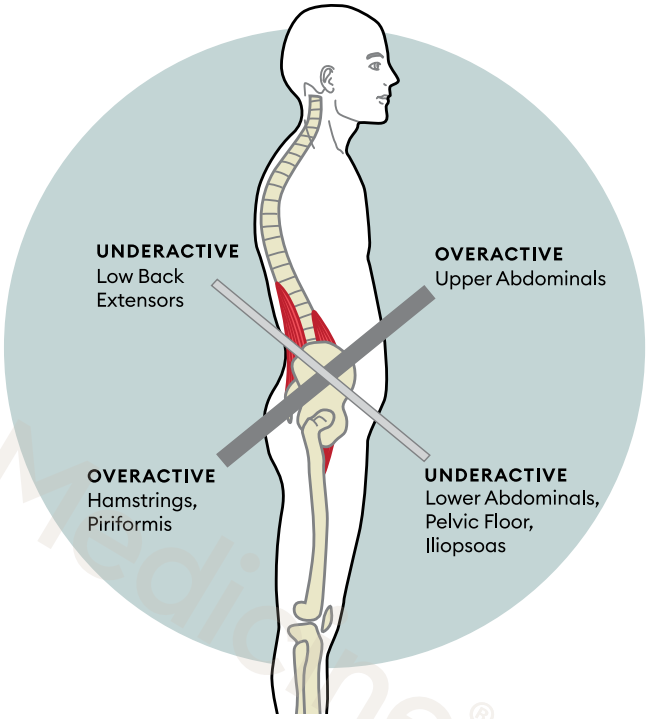
- Pelvis: increased anterior tilt
- Potential consequences for breathing
  - » Movement in thorax & thoracolumbar junction ↓
  - » Dysfunctional breathing patterns with reduced posterior expansion
  - » Poor relationship between diaphragm and pelvic floor



CHAITOW, BRADLEY & GILBERT, 2014B; KEY ET AL., 2008A; KEY ET AL., 2008B; KEY, 2010

Anterior pelvic crossed pattern

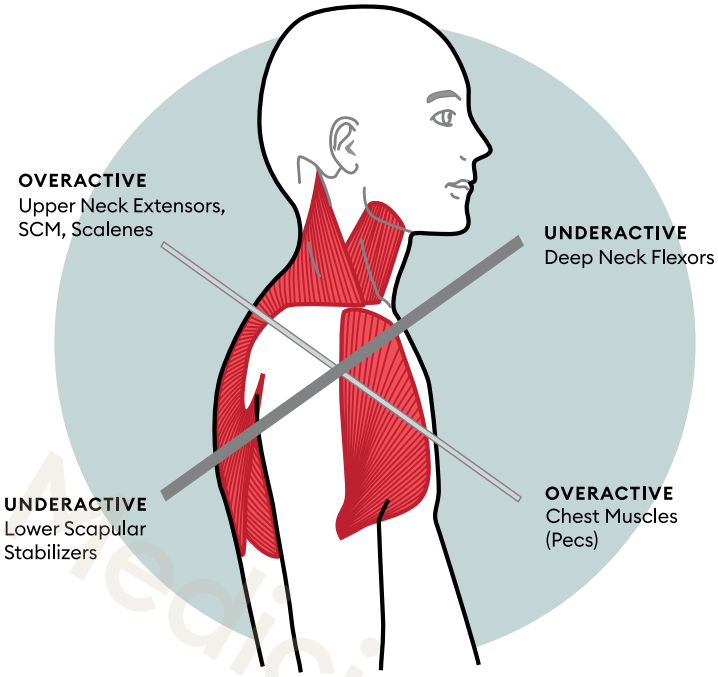
- Pelvis: anterior shift with increased posterior tilt
- Potential consequences for breathing
  - » Descent of the diaphragm ↓, upper chest breathing ↑
  - » Contribution of thorax in movement ↓
  - » Poor relationship between diaphragm and pelvic floor



CHAITOW, BRADLEY & GILBERT, 2014B; KEY ET AL., 2008A; KEY ET AL., 2008B; KEY, 2010

Shoulder crossed pattern

- Shoulders: round, upper thoracic kyphosis ↑, forward head posture
- Potential consequences for breathing
  - » Tendency for upper chest breathing, tendency towards hyperventilation
  - » Breath holding



CHAITOW, BRADLEY & GILBERT, 2014B; KEY ET AL., 2008; KEY, 2010

Physiology & Biochemistry of Respiration

Respiratory gases – CO_2

- **Narrow range** for blood gas levels
- **Chemoreceptors in aorta & carotid artery** monitor O_2 and CO_2 levels
- **CO_2** concentration is **strongest stimulus** for breath regulation

CO_2 & tissue oxygenation (Bohr effect)

- CO_2 produced through **cellular respiration**
- **Bohr effect:** CO_2 must be present for O_2 to be released from Hb and for tissues to be oxygenated (e.g. in exercising muscle)

High CO_2 in bloodstream = improved O_2 delivery

Low CO_2 in bloodstream = tissues less oxygenated

APPLICATION	
	**Breath holds:** increasing O_2 delivery throughout body by increasing CO_2 tolerance
	Rapid and / or big breathing, "superventilation": can deplete CO_2 stores (body dumps more CO_2 into lungs to maintain stable levels of O_2 and CO_2) → drop in arterial and alveolar CO_2 levels → tissues less oxygenated

BOITEN ET AL., 1994

CO_2 & smooth muscle dilation

- Smooth muscles governed by autonomic nervous system; e.g. in blood vessels, airways
- Highly responsive to CO_2

High CO_2 (hypercapnia) = expansion of blood vessels (vasodilation)

Low CO_2 (hypocapnia)= narrowing of blood vessels (vasoconstriction)

APPLICATION	
	**Sympathetic arousal and resulting hyperventilation:** vessels narrow → sensation of "tummy tightening" (evolutionary perspective: getting ready for action / attack)

Respiratory gases – O_2

- Most O_2 travels with **"hemoglobin taxi"**, some O_2 dissolved in **blood plasma**
- **Bohr effect:** CO_2 holds key to O_2 delivery to tissue; ensures that blood O_2 stays saturated at about 98%
- **Low Hb** concentrations: **reduced O_2-carrying** capacities

APPLICATION

Breath holds: impact through O_2 „second" to CO_2 impact; cellular respiration would eventually cease (eventual result would be cell death); heart muscle especially sensitive to this

Respiratory gases – Nitric oxide (NO)

Background	• Produced by all life forms and in many different tissues • Nobel prize in 1998: role of NO as signaling molecule
BP / blood flow	• Produced by innermost cell layer of arteries • Spreads through cell membranes to smooth muscle cells → capillary walls relax → impact on BP & blood flow
Nervous system	• Neurotransmitter within NS • Brain has more NO than rest of body • NO promotes learning, memory recall
Immune system	• NO can enhance immune regulation • NO has anti-inflammatory properties

Nitric Oxide (NO) & pranayama

Nasal breathing, humming	• Large amounts of NO produced in nasal cavity, breathed in through airways → optimal in nasal breathing • NO can improve ventilation-perfusion rate in lung & can relax smooth muscle in bronchial tree → O_2 uptake ↑ • Humming: nasal NO ↑

SANCHEZ-CRESPO ET AL., 2010; TÖRNBERG ET AL., 2002; WEITZBERG & LUNDBERG, 2002

CO_2 & pH regulation

- Blood acidity mainly determined by CO_2
- **pH level** influences all organs → balance is imperative to life
- CO_2 level: **instant way of pH regulation**

High CO_2 (hypercapnia) = high acidity = low pH = higher breathing drive

Low CO_2 (hypocapnia)= low CO_2 (hypocapnia) = low acidity = high pH = lower breathing drive

APPLICATION	
	**Breath holds, exercise** → CO_2 production ↑ → CO_2 builds up in blood → blood becomes acidic (pH ↓) → stimulates inspiratory center to increase respiration and limit further pH changes
	Hyperventilation without additional CO_2 production (e.g. in panic attack): too much CO_2 / acid being blowed off → pH climbs high → breathing into paper bag helps to inhale expelled CO_2, restoring needed level of pH/acid

Breathing & pH regulation

pH	CO_2	Effects
Acidosis		
7.1	High ↑	Coma
7.2	↑	Hypercapnia symptoms (drowsiness, confusion)
7.3	↑	Breathing reflex stimulated
7.4	↑	Normal
7.5	↑	Mild hypocapnia symptoms (light-headedness, weakness), breathing reflex suppressed
7.6	↑	Moderate hypocapnia symptoms (paresthesias, confusion, twitches)
7.7	↑	Coma
7.8+	Low ↓	Death
Alkalosis		

GILBERT, 2014

Breathing patterns variations

Causes:

Physiological	Pathological	Voluntary / therapeutically induced

Forms:

Hypoventilation

- Respiration too shallow, in-adequate to perform required gas exchange
- Increases concentrations of blood CO_2 (hypercapnia); reduces O_2 (hypoxia)
- Alters body's pH towards acidosis

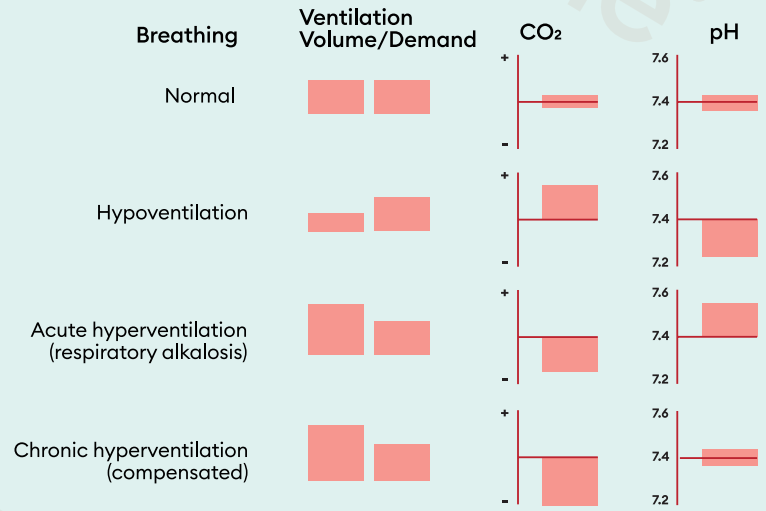
Restrictive

- Breathing in excess of metabolic requirements
- Reducing CO_2 concentrations in the blood to below normal (hypocapnia)
- Alters the body's pH towards alkalinity

Breathing patterns and pH

Breathing patterns and pH changes.

Adapted from Gilbert (2014)



Adapted from Gilbert, C. (2014). Biochemical aspects of breathing. In: *Recognizing and treating breathing disorders*. Eds.: Chaitow L, Bradley D, Gilbert C. Elsevier, London.

Voluntary hypoventilation/ hypoxia

Tools:

- Breath holding, CO_2 tolerance/ air hunger training
- Related concepts: hypoxic training, intermittent hypoxia

Strong metabolic stressor

- CO_2 levels ↑
- Muscle deoxygenation

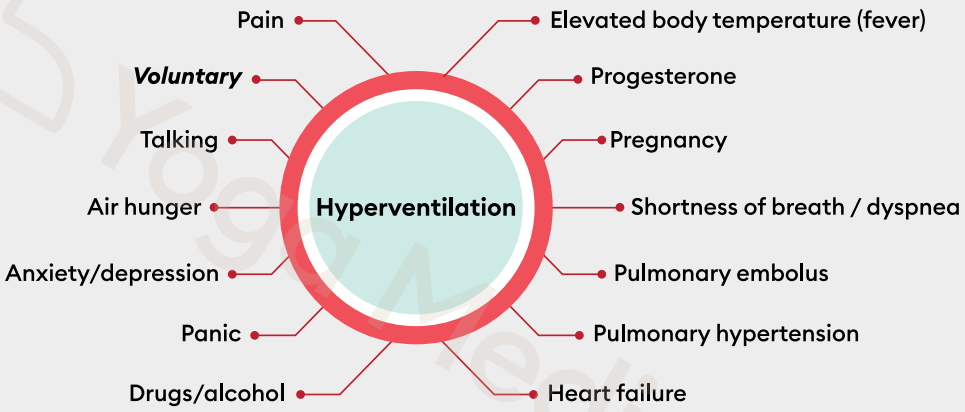
Adaptations

- Hb concentration ↑
- CO_2 sensitivity ↓
- Lung ventilation, stroke volume ↑
- ANS improvement // HRV ↓; brain responses rel. to anxiety, stress, fear states
- Immune system response modulation ↑

CRITCHLEY ET AL., 2015; GIRARD ET AL., 2020; HOLFELDER 2019; KUME ET AL., 2016; MORIYAMA ET AL., 2022; RYBNIKOVA ET AL., 2022; SALES DE CAMPOS ET AL., 2023; TIMON ET AL., 2023; TOUBEKIS ET AL., 2017; UZUN ET AL., 2023; WOORONS ET AL., 2016

Factors initiating hyperventilation

Hyperventilation can have physical and / or emotional basis (neurological basis is rare); it can also be induced voluntarily.



adapted from Gardner, 1996

Hyperventilation

Acute	Chronic
• **CO_2 ↓↓ (hypocapnia) at beginning** of voluntary hyperventilation • Rapid onset of **respiratory alkalosis** in voluntary hyperventilation (pH ↑) • **Reduced blood flow to brain & tissues** (reduced CO_2 acts as vasoconstrictor)	• **Within 6-72 hours** • Body gets used to lower CO_2 levels (“**cultivated CO_2 intolerance**”) • May lead to stronger urge to breathe and shortness of breath

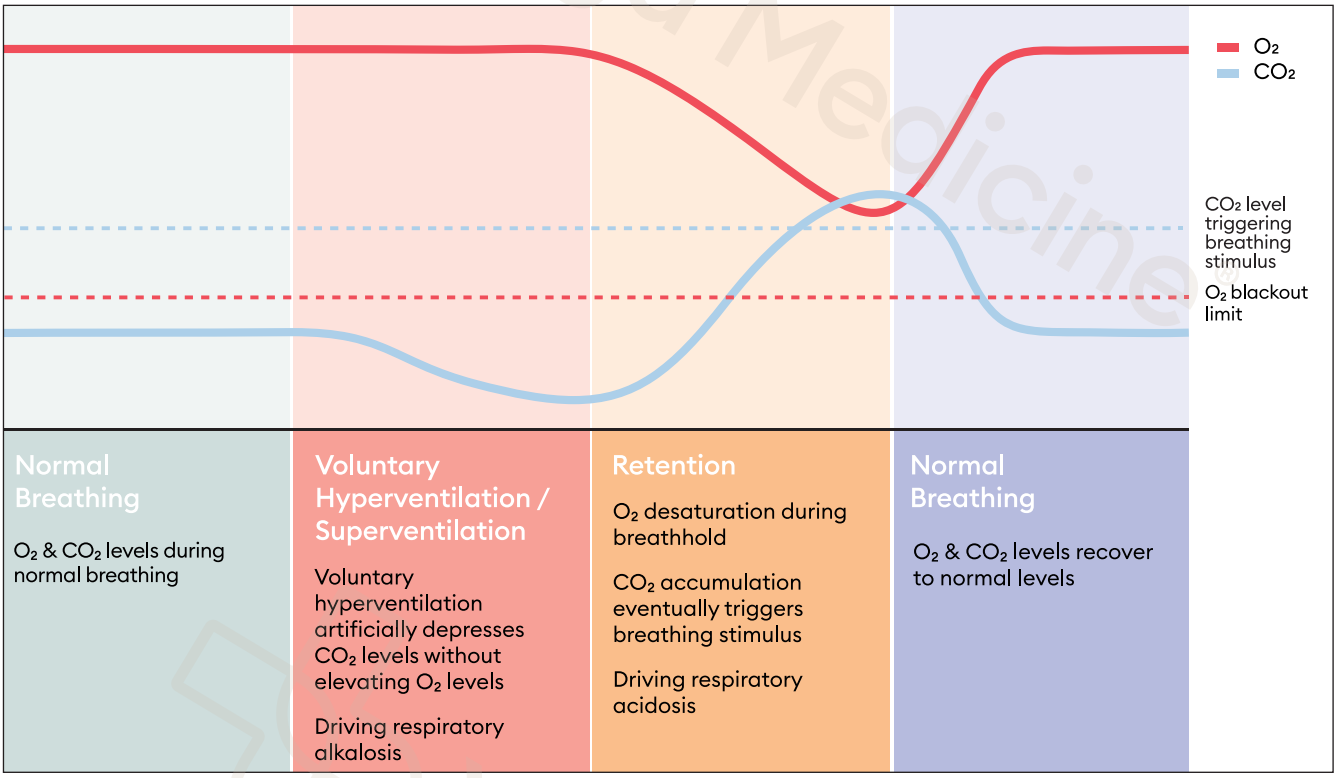
BRADLEY, 2014; GARDNER, 1996

Effects of acute hyperventilation

Neural	• Involuntary muscle contractions, cramping • Prickling, burning sensations
ANS related	• Sympathetic dominance: sweating, clammy hands • Autonomic instability of blood vessels: labile BP
Blood flow	• Brain ↓: dizziness, visual disturbances, headache, tremor, tinnitus, hallucination, unilateral tingling • Skin: vasoconstriction, cold extremities • Muscle: first vasodilation, then vasoconstrictionl

Voluntary hyperventilation + hypoxia

APPLICATION	
	**Voluntary hyperventilation / "supverventilation" followed by breath hold** *(e.g. Kapalabhati + breath hold, Wim Hof, Conscious Connected + breath hold)*
	CO_2 levels ↓ → respiratory alkalosis → breathing drive ↓ → able to hold breath longer → temporary hypoxia (less than normal O_2 levels in blood) → respiratory acidosis → breathing stimulus



When is overbreathing acceptable?

Examples

- Preparation for action
- As means to reduce excess acid levels
- Luteal phase of menstrual cycle (progesterone)
- Active exercise

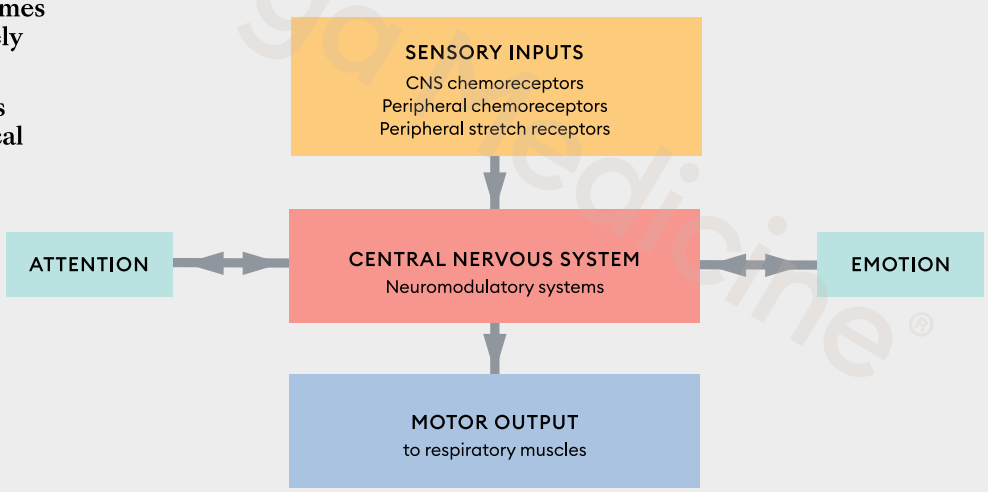
CHAITOW, BRADLEY, & GILBERT (2014)

Breath and the Nervous System

Regulation of breathing / breathing patterns

Breathing is sometimes conscious, but largely unconscious.

Breathing pattern is a psychophysiological construct.



Gargaglioni et al., 2019
Harbour et al., 2022

Regulation of breathing – CNS

- Signal from **brainstem**
- **Motor neurons regulated by respiratory centers** control respiratory muscles
- **Inspiratory rhythm** governed by preBötzinger complex in medulla
- **Expiratory rhythm** generator: lateral parafacial; in active expiration

ASHHAD ET AL., 2022; BELLINGHAM, 1998; DEL NEGRO ET AL., 2018

Regulation of breathing – CO_2

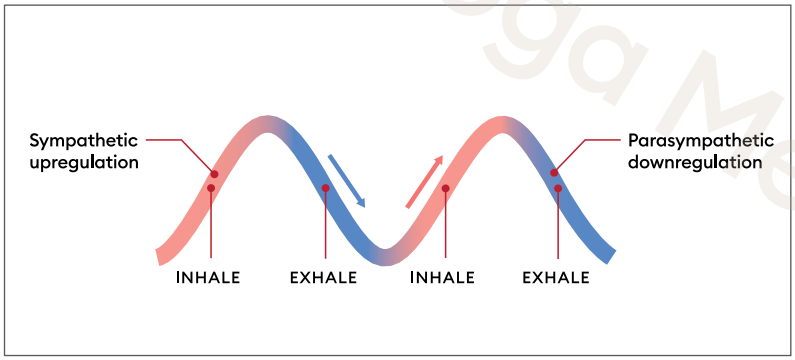
- **CO_2 level strongest stimulus**
- **Chemoreceptors in aortic arch and carotid artery**
  - » CO_2 ↑: blood acidity ↑
  - » To counter this: brain stem sends signal to increase respiration rate
- **CO_2-sensitive brain areas**
  - » CO_2 ↑: rate and depth of respiration ↑ (so CO_2 can be removed)

GARGAGLIONI ET AL., 2019

Regulation of breathing – stretch receptors

- **Pleurae, bronchioles, and alveoli contain stretch receptors**
- **Hering-Breuer reflex:**

Up- and down-regulation of breathing



Changes through breathing
cycle by cycle (seconds)

	Inspiration	Expiration
Pupil diameter	↑	↓
Reaction time	↑	↓
Fear response	↑	↓
Memory retrieval	↑	↓

ASHHAD ET AL., 2022

APPLICATION

Upregulating	• Focus on inhale • Superventilation / power breathing • Eyes focused	• Sitting up • Moving
Downregulating	• Pronounced / longer exhales • Slow, deep breathing • Eyes closed / peripheral vision	• Supine • Stillness

Respiratory sinus arrythmia (RSA)

- Respiratory sinus arrhythmia: HRV in synchrony with respiration

Inhale: HR ↑ Exhale: HR ↓

- Measure for ANS balance & respiratory-circulatory interaction
- Mechanisms
  - » Variation of vagal activity
  - » Atrial stretch reflex (Bainbridge)
  - » Baroreceptor reflex
  - » Pulmonary stretch reflexes (Hering-Breuer)
  - » Peripheral chemoreflexes

CUCERI ET AL., 2020; FANNING ET AL., 2020; SKYTIOTI & ELSTAD, 2022; YASUMA & HAYANO, 2004

Emotion, ANS, cognition & breathing

Emotion, cognition ←→ breathing

- **Slowing** of respiration shifts ANS balance towards **PNS** (→ BP, HR, HRV)
- "Micro-dosing" breathwork

Long term plasticity of breathing practices (> minutes)			
Anxiety	↓	Calm	↑
Panic	↓	Sleep	↑
Depression	↓	Motor skills	↑
Stress	↓		

ASHHAD ET AL., 2022; BERNARDI ET AL., 2001; GERRITSEN & BAND, 2018; DICKT ET AL., 2018; FINCHAM ET AL., 2023; HECK ET AL., 2019, MAGNON ET AL., 2021; MELNYCHUK ET AL., 2018; PARK ET AL., 2020; PERCIAVALLE ET AL., 2017; PRAMANIK ET AL., 2009; SCHULZ ET AL., 2016; TAVARES ET AL., 2017

Emotion & cognition - pathways

Speed & depth of breath	• Breathing pattern → signal processing in brain areas with higher functions (slower breath → calm)
Nasal breathing	• Mechanosensory nasal signals → brain regions associated with emotion and cognition
Pulmonary vagus nerve afferent activity	• Pulmonary stretch receptors • May alleviate symptoms of clinical depression
Changes in blood gases (CO_2, O_2)	• Acute CO_2 ↑ can induce panic attack-like behavor • Deep breaths → acute lowering of CO_2 → calm

ASHHAD ET AL., 2022; BANZETT ET AL., 2021; CARRENO & FAZER. 2017; GERRITSEN & BAND, 2018; MEURET ET AL., 2008; NOBLE & HOCHMANN, 2019; PERL ET AL., 2019; YACKLE ET AL., 2017; ZELANO ET AL., 2016

Yawning

- Prolonged inspiration (wide open mouth), shorter expiration
- **Triggers**
  - » Low-vigilance state of brain, wake-sleep-transistion
  - » Stressful events, hunger, psychoactive drugs, neurological diseases
  - » Contagiousness
- **Function (hypothesis)**
  - » Stretching of airway muscles to preserve lumen and secure long-term oxygenation

BOITEN ET AL., 1994; DOELMAN & RIJKEN, 2022

Sighing

- **Rhythmical physiological sighing**
  - » About every 5 min, re-inflating alveoli
- **Sighs associated with emotional state**
  - » Relief, grief, happiness, anxiety, fatigue, boredom, excitement
- **Cyclic sighing as breathwork practice**
  - » 5 min intervention
  - » Breathwork improved mood and physiological arousal (respiratory rate, HR, HRV) more than meditation; **cyclic sighing most effective**

BALBAN ET AL., 2023; BOITEN ET AL., 1994; DELNEGRO ET AL., 2019

How to teach pranayama – general considerations

Respiration Variables

Rate

- Number of respiratory cycles per minute
- Length of each phase (inhale, exhale, retention)

Depth (volume)

- Tidal volume is volume of air moved during one cycle of respiration

Duration

- Length of practice

Pathway

- mouth vs. nose, left vs. right nostril

Position

- prone, supine, or in asanas

How to start teaching pranayama

- Repetition
- Time of day
- Position

Progression:

- Duration
- Retention
- Bandhas

Rules of thumb

- Start simple
- Effortless
- Recovery breath as needed
- Inhale (puraka) & inhale retention more yang/SNS
- Exhale (rechaka) & exhale retention more yin/PNS
- Right nostril yang/SNS
- Left nostril yin/PNS

Contraindications

Serious Heart & Lung conditions	Check with Dr & keep it simple (avoid kapalabhati, bhastrika, & extended retention)
Hypertension	Focus on exhales, exhale ≥ inhale, avoid kapalabhati & bhastrika, avoid extended breath retention
Elevated intraocular pressure	Exhale ≥ inhale, no inhale retention, avoid kapalabhati & bhastrika
Hypotension	Inhale & inhale retention focus
Epilepsy	No kapalabhati or bhastrika
Pregnancy	No kapalabhati, bhastrika, uddiyana bandha, or pranayama practices that increase BP **Beneficial in pregnancy:** ujjayi, chandra bhedana, nadi shodhana, sama vritti, lengthen exhale
Kapalabhati & Bhastrika	High blood pressure, heart disease, brain tumors, stroke, vertigo, stomach or intestinal ulcers, GERD, gastritis, glaucoma, diarrhea, systemic inflammation, & hyperventilation
Extended Kumbhaka	Pregnant, uncontrolled high blood pressure, history of heart attack or stroke, aneurysm of the aorta or in the brain, arrhythmia or tachycardia, cancer, kidney disease, or poor lung function.
Be mindful during practice of	Increasing tension, loss of easefulness, restlessness, irritability, heaviness, heat

Uses

Depending on the technique can be helpful for:

- Nervous system regulation (SNS & PNS), fatigue, stress, to calm or stimulate, concentration/focus, HRV, emotional regulation, anxiety, depression, respiratory & cardiovascular function, blood pressure regulation, and supporting immune function. Rhythmic movement of diaphragm supports circulation to the organs (liver, spleen, stomach, kidneys, intestines), lymphatic & venous return to the heart, digestion & elimination/peristalsis.

Traditional benefits:

- Supports digestion, vigor & vitality, serenity, perception, memory, and sharpens the intellect. Purify & regulate the nadis or energetic channels. Cleanses the organs, senses, mind, intellect, & ego. Prepares the body & mind to be fit for concentration/dharana & meditation/dhyana. Pranayama is the window of the self.
- "Occasionally, the same set of pranayama creates uneasiness. Be quick to switch over to a breathing pattern more conductive to the body and mind, and soothing to the nerves and brain, so that they are rejuvenated and refreshed. Pranayama should not become a blind routine." – BKS Iyengar

Pranayama Foundations

Observing Breath

- Breath as the bridge between mind & body
- Effortless is key!!
- Follow the breath
- Listen, do not disregard what the breath is telling you
- Notice the story of needing breath

BREATH AWARENESS: WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Neurocognition**	• Efficient use of attentional resources ↑ • Time spent in calm state ↑ (internal vs. external point meditation)

SCHÖNE ET AL., 2018; SHARMA ET AL., 2022

Diaphragmatic breathing

- "Belly breathing"
- Diaphragm movement
- Drives thoracic pump to increase venous & lymph return
- Abdominal organ massage (digestion, peristalsis, reproductive organs, liver, kidneys)
- Vagus nerve stimulation

DIAPHRAGMATIC BREATHING: WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Lung function, biomechanics**	• Correlation: movement of diaphragm ↑ - changes in lung volume ↑ • Facilitates slow respiration
	**Cardiovascular system**	• Venous return ↑ (esp. at 6 breaths/ min)
	**Neurocognition/-physiology**	• Stress (BP, cortisol) ↓

BYEON ET AL., 2012; DICK ET AL., 2014; HOPPER ET AL., 2019; KOLAR ET AL., 2009; STROMBERG ET AL., 2015

Inhalation (Puraka)

- Yang, energizing
- SNS dominant
- Increases BP
- Lungs as an instrument for receiving energy
- Focus on 3D expansion of ribs

Exhalation (Rechaka)

- Yin, calming, surrender ego
- PNS dominant
- Lowers BP
- Release, let go
- Maintain lift of ribs without muscular effort

Retention (Kumbhaka)

- In its essence, pranayama is Kumbhaka
- Retention magnifies the effects of that phase of breath

- CO_2 increases
- Increased CO_2 tolerance
- Increasing CO_2 levels (hypercapnia) → vasodilation→ increased cerebral blood flow

- Do not force
- Should not cause tension, red face/eyes, or irritation
- Maintain lift of spine throughout

Antara kumbhaka (inhale retention or puraka kumbhaka)

- Traditionally to increase energy, confidence, endurance, capacity for work, improve depression, increase BP
- Not for uncontrolled high BP, pregnant, or cardiac disorders

Bahya kumbhaka (exhale suspension or rechaka kumbhaka

- Increased parasympathetic activation, traditionally for nervous tension, muscular tension, high BP
- Extended not for low BP

Both

- Not for heart issues, history of heart attack or stroke, aneurysm of the aorta or in the brain, arrhythmia or tachycardia, cancer, kidney disease, sick, or poor lung function.

KUMBHAKA: WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Cardiovascular system**	• BP, HR ↑
	**Cerebral blood flow**	• ↑

NIVETHITHA ET AL., 2017; NIVETHITA ET AL., 2021

VOLUNTARY HYPOVENTILATION: WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Cardiovascular system / metabolism**	• Repeated sprint training → greater muscle deoxygenation • Performance ↑
	**Motor system**	• Coordination ↑ after breath hold training (swimming)

LEMAÎTRE ET AL., 2009; ROBERTSON ET AL,, 2020; TRINCAT ET AL., 2017; WOORONS ET AL., 2017

Digital Pranayama

- Delicate, usually right thumb & ring/pinky fingers
- Close off at cartilage
- Correct amount blocked off creates a smooth, even resonance
- Adjust width to adjust timing of breath
- Listen for sound variations
- Traditionally avoid with headaches, anxious, restless, nose blocked, runny nose, fever or immediately after a fever

Bandhas

Bondage, joining together or catching hold of

- Direct energy, prevent dissipation of energy, support the flow of prana

Jalandhara Bandha

- Upper lock, separates cool lunar plexus from solar plexus for vitality & longevity
- Used in inhale retention
- Lift sternum to meet chin, stretch sides of neck

Uddiyana Bandha

- Lifts energy up from lower abdomen toward head
- Used in exhale retention
- Create vacuum, draw belly up & in, relax abdominals

Mula Bandha

- Counteracts the downward flow of energy
- Used in inhale retention
- Lift between anus & genitals

Samavritti	
OTHER NAMES	**Equal ratio breathing**
NOTES	Use several recovery breaths between each round at first, then less over time
PROGRESSION	1. Begin with 1:1 (inhale:exhale) 2. Then add inhale retention and build up- 1: ¼ :1, 1: ½ :1, 1: ¾ :1, 1:1:1 (inhale:retention:exhale) 3. Then add exhale retention and build up- 1:1:1: ¼, 1:1:1: ½, 1:1:1: ¾, 1:1:1:1 (inhale:retention:exhale:suspension)
BOX / TACTICAL BREATHING: WHAT RESEARCH SUGGESTS RIGHT NOW	
	**Neurocognition/-physiology** • Physiological arousal (HR) ↓

BALBAN ET AL., 2023; BOUCHARD ET AL., 2012; RÖTTGER ET AL., 2021

Visamavritti	
OTHER NAMES	**Irregular ratio breathing**
NOTES	• Traditionally heavy on inhale & inhale retention which is why it is used with caution • 4:7:8, etc (more energizing with out lifting BP) • 4:4:8:2, etc (more calming)
PROGRESSION	Many progression options like: 4:4, 4:2:4, 4:2:6, 4:2:6:2, 4:4:8:2, 4:2:6, 4:4

Pranayama Techniques

Ujjayi	
OTHER NAMES	**Victorious, Ocean Breath**
NOTES	• Do not inflate abdomen, 3D movement of ribs • Receive the breath, not forceful • Louder is more heating
PROGRESSION	1. Ujjayi on its own 2. Ujjayi with inhale retention, until able to hold for 10secs 3. Ujjayi with exhale retention, until able to hold for 10secs 4. Add mula bandha on inhale retention 5. Add uddiyana bandha on exhale retention 6. Both inhale retention with mula bandha & exhale retention with uddiyana bandha (advanced, not for group classes)

SLOW, DEEP BREATHING: WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Lung function**	• 6 breaths/ min optimal for improving alveolar ventilation & reducing dead space
	**Cardiovascular system**	• BP ↓ • Stress on cardiovascular system ↓ → can help with athlete's recovery
	**Neurophysiology**	• HRV, RSA ↑ • Shifting ANS balance towards PNS dominance

BERNARDI ET AL., 1998; BILO ET AL., 2012; JOSEPH ET A., 2005; MIGLIACCHIO ET AL., 2023; RADAELLI ET AL., 2004; RUSSO ET AL., 2017; ZACCARO ET AL., 2018; ZHANG ET AL., 2016

Viloma	
OTHER NAMES	**Against the grain, interrupted breathing**
NOTES	• Supine to begin • Hold onto diaphragm in pauses • On inhale or exhale
OPTIONS	• Counted (inhale 2-3, pause 2-3, repeat until full→ slow deep ujjayi exhale) • By area (3-part breathing: belly→ ribs→ chest)
ADVANCED OPTIONS	**Not for group classes** • Add retention after villoma • Both inhale & exhale viloma

Anuloma

OTHER NAMES	**With the natural order**
TECHNIQUE	Seated: 1. Inhale through both nostrils 2. Exhale with both nostrils partially blocked » OR exhale through alternating partially blocked nostril
NOTES	• Exhale will be longer than the inhale= PNS effects • Deflate tension/stress • Traditional uses: cleanses nasal passages, lowers BP, calming
ADVANCED OPTIONS	• Add retention, bandhas, villoma

Pratiloma

OTHER NAMES	**Against the natural order**
TECHNIQUE	Seated: 1. Inhale through 1 or both partially blocked nostrils 2. Ujjayi exhale through both nostrils
NOTES	• Traditionally inhale is longer than the exhale= SNS effects • Less commonly used, unless lengthen exhale too • Traditional uses: increase BP, energize

Nadi Shodhana

OTHER NAMES	**Alternate nostril breathing**
NOTES	• Balancing breath (yin/yang, PNS/SNS, warm/cool, right/left body, right/left brain, frontal lobe executive function/primitive brainstem) • Traditionally for: even & balanced action in all aspects of the brain, peace, poise, harmony, tap into innermost self, calm nerves, serenity, prep for dhyana
PROGRESSION	1. Alternate nostril no retention 2. Through partially closed nostril 3. Add retention 4. Add bandhas

Nadi Shodhana

WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Neurocognition**	• Cognitive ability ↑ (working memory; reaction time ↓, accuracy ↑)
	**Cardiovascular system**	• HR, BP ↓ • Slowing or breath, RSA ↑ → parasympathetic tone ↑
	**Cerebral blood flow**	• Cerebral blood flow velocity (correlated w cerebral blood flow) ↓

BHARGAVA ET AL., 1988; BHAVANI ET AL., 2014; DEEPESHWAR & BUDHI, 2022; JOVANOV, 2005; KUMAR ET AL., 2022; RAGHURAJ & TELLES, 2008; SINHA ET AL.; 2013

Surya Bhedana & Chandra Bhedana

Surya - sun breath

- Inhale left/yang nostril
- Exhale right/yin nostril
- Energize, warm, SNS
- Exhale out heavy, lazy

Chandra - moon breath

- Inhale right/yin nostril
- Exhale left/yang nostril
- Calm, relax, quiet, PNS
- Exhale out restlessness, irritability

Unilateral nostril breathing

WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Cardiovascular system / neurophysiology**	• LNB: HR, BP ↓ • RNB: HR, BP ↑
	**Respiratory physiology**	• NO availability in congested side of nose higher during UNB • Nasal cycle: accumulation of NO in congested side
	**Neurocognition / brain activity**	• LNB: activation in posterior brain areas ↑ (meditative state) • RNB: cognitive ability ↑ // anxiety ↓, language ↑ (stroke patients)

BHAVANI ET AL., 2014; DEEPESHWAR & BUDHI, 2022; MARSHALL ET AL., 2014; NIAZI ET AL, 2022 ; RAGHURAJ & TELLES, 2008; STASSEN ET AL., 2021

Surya Bhedana & Chandra Bhedana

WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Cardiovascular system / neurophysiology**	• Surya Bhedana: BP, HR ↑ sympathetic activation • Chandra Bhedana: BP, HR ↓ parasympathetic activation

BHAVANAI ET AL., 2014; RAGHURAJ & TELLES, 2008; TELLES ET L, 1996

Bhramari

OTHER NAMES	**Bee's breath**
TECHNIQUE	• A vibrating, humming sound produced while exhaling through nose • Start supine, then seated • Fingers cover eyes/ears/nose or ears/skull
NOTES	• Stimulate vagus nerve, quick shift to PNS • Enhances flexible cognitive control • Great for stress, tension, insomnia, quick calming

WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Neurocognition / -physiology**	• ANS: Parasympathetic dominance • CNS: enhanced cognitive control
	**Cardiovascular system**	• Unclear picture regarding HR, BP
	**Lung function**	• ↑ • Improvement in chronic rhinosinusitis

CAMPANELLI ET AL., 2020; RAJESH ET AL., 2014; VIALATTE ET AL., 2009; ABISHEK ET AL., 2019; GHATI ET AL., 2021; KUPPUSAMY ET AL., 2017A; KUPPUSAMY ET AL., 2017B; KUPPUSAMY ET AL., 2020A; KUPPUSAMY ET AL., 2020B; MOOVENTHAN & KHODE, 2014; NIVETHITHA ET AL., 2017; NIVETHITHA ET AL., 2021; PRAMANIK ET AL., 2010; TRIVEDI & SABOO, 2021; TRIVEDI ET AL., 2023

Bhastrika

OTHER NAMES	**Bellows breath**
NOTES	• Forceful inhalation and exhalation • Increase in heart rate, reduced CO2 levels (hypocapnia) → vasoconstriction, reduced cerebral blood flow
TRADITIONAL	• For: invigorates spleen, liver, pancreas, digestion, and abdominal muscles. Clear sinuses & runny nose. Refresh & awaken the brain. Generates prana for the entire body, but too much can wear out the system. • Not for: exhaustion, weak or poor lung capacity, pregnant, glaucoma, detached retina, perhaps other eye issues, high BP, nose bleeds, ear infections, uterine prolapse, during menses
CONTRA-INDICATED	• Epilepsy

WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Neurocognition / -physiology**	• Visual & auditory reaction time ↓
	**Cardiovascular system**	• Faster paced/ forceful: BP, HR, cardiac output ↑ • Slow paced (6 breaths/ min): BP ↓ , HR ↓
	**Cerebral blood flow**	• ↓
	**Lung function**	• ↑

CAMPANELLI ET AL., 2020; NIVETHITHA ET AL., 2017; BHAVANANI ET AL., 2003; BHUDI ET AL., 2019; NIVETHITHA ET AL., 2017; NIVETHITHA ET AL., 2021; PRAMANIK ET AL., 2009; VEERABHADRAPPA ET AL., 2011

Kapalabhati		
OTHER NAMES	**Skull-shining breath**	
NOTES	• Also a Kriya practice, milder than bhastrika • Forceful exhale • Passive inhalation and active exhalation • Increase in sympathetic activation	
TRADITIONAL	• For: invigorates spleen, liver, pancreas, digestion, and abdominal muscles. Clear sinuses & runny nose. Refresh & awaken the brain. Generates prana for the entire body, but too much can wear out the system. • Not for: exhaustion, weak or poor lung capacity, pregnant, glaucoma, detached retina, perhaps other eye issues, high BP, nose bleeds, ear infections, uterine prolapse, during menses	
CONTRA-INDICATED	• Epilepsy	
WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Neurocognition / -physiology**	• Shifting ANS balance towards SNS dominance (BP, HR ↑) • Cognitive performance ↓
	**Cardiovascular system**	• BP, HR, CO ↑
	**Cerebral blood flow**	• Cerebral blood flow velocity (→ cerebral blood flow) ↓
	**Motor system**	• Handgrip strength ↑
WIM HOF (WHM), FAST BREATHING (FB): WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Neurocognition / -physiology**	• FB: reaction time, movement time ↓; arousal, hindrance ↑ • WHM: pain perception ↓
	**Immune system**	• WHM: epinephrine ↑ (independent of breath retention) • WHM: anti-inflammatory effect (cytokine response)

CAMPANELLI ET AL., 2020; JOSHI & TELLES, 2009; KUMAR ET AL., 2022; STANCÁK ET AL., 1991A; STANCÁK ET AL., 1991B; TELLES ET AL., 2014; TELLES ET AL., 2019; BUCAHANAN & JANELLE, 2021; ZWAAG ET AL., 2022; ZWAAG ET AL., 2023

Sitali & Sitkari		
OTHER NAMES	**Cooling breath**	
NOTES	• Sitali: inhale through a curled tongue • Sitkari: inhale over tongue	
TECHNIQUE	1. Inhale retention with jalandhara (with or without mula bandha)- ujjayi exhale 2. Exhale through partially closed nostrils 3. Exhale through alternate nostrils (or alternate partially closed nostrils)	
TRADITIONAL	• Cooling, soothes, good for eyes & ears, for fever, activates liver & spleen, improves digestion, for halitosis	
WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Metabolism**	• Body temperature ↑ • O_2 consumption ↑ → pointing to a mild hypermetabolic state

CAMPANELLI ET AL., 2020; RAJESH ET AL., 2014; VIALATTE ET AL., 2009; TELLES ET AL., 2020

Nauli		
OTHER	**also a Kryia practice**	
TECHNIQUE	• Create vacuum after exhale to draw belly up & in, relax abdominals	
NOTES	Hypopressives: • Relaxation of diaphragm, decrease intra-abdominal pressure • Combination of exhale retention and pressure changes • Can activate pelfic floor muscles, abdominals • Used in urinary incontinence and postpartum	
HYPOPRESSIVES: WHAT RESEARCH SUGGESTS RIGHT NOW		
	**Motor system/ posture**	• For pelvic floor strength, ideally + pelvic floor muscle training • Posture control, trunk muscle contraction ↑ • Diaphragm thickness, strength during inspiration ↑

DA CUNA-CARRERA ET AL., 2021; NAVARRO BRAZALES ET AL., 2019; JACOMO ET AL., 2020; MORENO-MUNOZ ET AL., 2021; VICENTE-CAMPOS ET AL., 2021

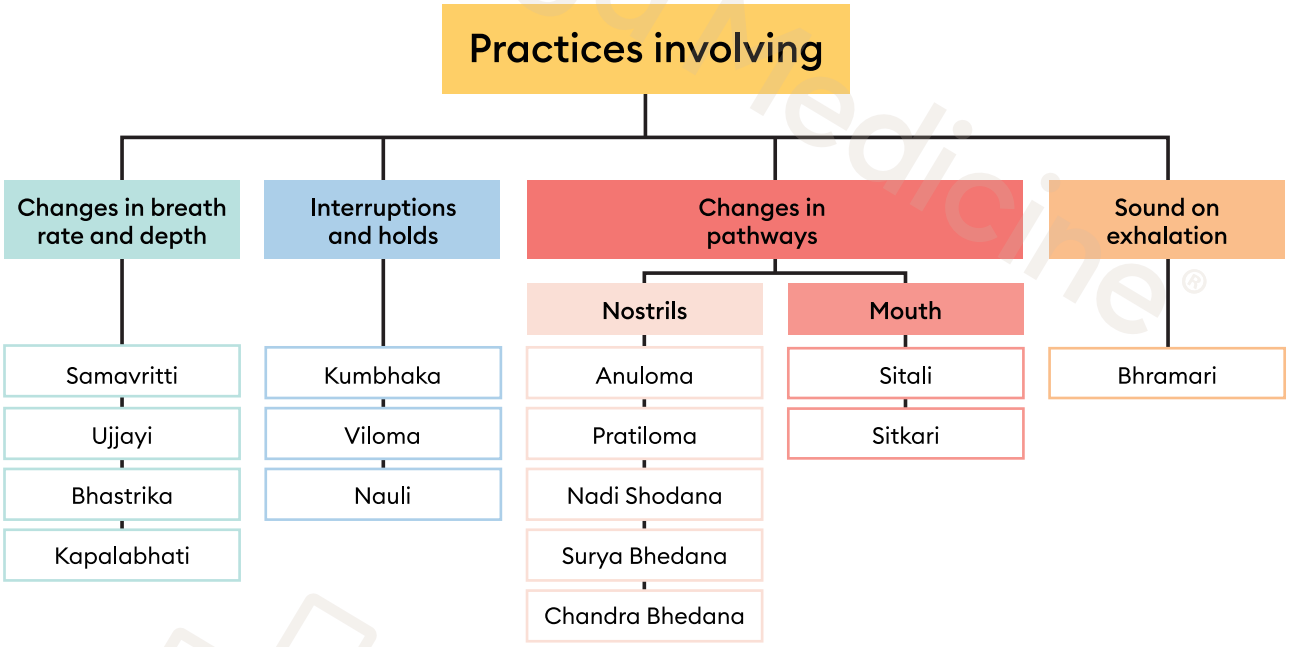
Progression

1. Shorter breath with recovery breath as needed
2. Longer, slower breath
3. Inhale retention (progressively longer)
4. Exhale retention (progressively longer)
5. Inhale retention with mula bandha & or jalandhara bandha
6. Exhale retention with uddiyana bandha
7. Both inhale & exhale retention
8. Adding other variations like viloma, anuloma, bhramari, right or left nostril, alternate nostril

9. Duration of practice

Sequencing Notes

- Prepare for easefulness throughout practice
- Simple practices prepare for more complex
- Follow up stimulating practices with calming/ focusing practices
- End with calm/focus, cooling, or easeful practices



Pranayama techniques - overview

Note: this categorization is based upon primary features of the techniques; some techniques may have multiple features (example: Nadi Shodana involves breathing through alternating nostrils and also breath holds)

Pranayama techniques - mechanisms