SLOW BREATHING
so simple – so complex

Luciano Bernardi

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A RELEVANT COMPONENT OF YOGA PRACTICE SEEMS AIMED AT SLOWING THE BREATHING RATE

WHAT ARE THE EFFECTS?
ARE THERE ANY ADVANTAGES?
some basics on respiration

(mouth) ventilation = br. rate x tidal volume

(alveolar) ventilation = br. rate x tidal volume - anatomical dead space ~ 0.15L
some basics on respiration

(mouth) ventilation = br. rate x tidal volume

(alveolar) ventilation = br. rate x tidal volume - anatomical dead space

This is what counts for GAS EXCHANGE

this determines the WORK OF BREATHING

~ 0.15L
some basics on respiration

mouth ventilation = br. rate x tidal volume

alveolar ventilation = br. rate x tidal volume - anatomical dead space ~ 0.15L

mouth (Liters/minute)

6 L = 12 x (0.5 - 0.15 L) → 4.2 L

6 L = 6 x (1 - 0.15 L) → 5.1 L
something **LESS** basic on respiration

**mouth** (Liters/minute)

\[
6 \text{ L} = 12 \times (0.5 - 0.15 \text{ L}) \Rightarrow 4.2 \text{ L}
\]

\[
6 \text{ L} = 6 \times (1 - 0.15 \text{ L}) \Rightarrow 5.1 \text{ L}
\]

**alveolar** (Liters/minute)

\[
5.1 \text{ L} = 6 \times (0.85 - 0.15 \text{ L}) \Rightarrow 4.2 \text{ L}
\]

**BUT, if I am happy with 4.2 L at the alveoli, when I slow down the breathing I can reduce my tidal volume further, in order to obtain 4.2L**
BUT, if I am happy with 4.2 L at the alveoli, when I slow down the breathing I can reduce my tidal volume further, in order to obtain 4.2 L.
BUT IN ADDITION:
- BETTER MATCHING OF AIR AND BLOOD IN THE LUNG
- BETTER GAS EXCHANGE
- BETTER VENTILATION/PERFUSION MATCHING (reduced Vd/Vt ratio)

SLOW-DEEP BREATHING INCREASES THE OXYGEN IN THE BLOOD

even lower stimulation of breathing → lower ventilation → lower work

SHALLOW-FAST BREATHING

SLOW-DEEP BREATHING

Bernardi et al, Lancet 1998
less need to breath has a major consequence:

readjustment of life-critical reflexes:

1) control of respiration
2) control of cardiovascular system
CHEMOREFLEX measures the stimulus to breath

chemoreflex = slope of the relationship between ventilation/CO2 or O2

progressive O2 reduction or progressive CO2 increase
Yoga and chemoreflex response to hypoxia and hypercapnia

Lucia Spicuzza, Alessandra Gabutti, Cesare Porta, Nicola Montano, Luciano Bernardi

1) **YOGA trainees**: lower ventilatory response to $O_2$ (or $CO_2$), both during slow or spont. breathing

2) **yoga-naive subjects**: chemoreflex dropped when breathing slowly!

THE LANCET • Vol 356 • October 28, 2000
CHALLENGING THE SLOW BREATHING DURING SIMULATED HIGH ALTITUDE

University of New Mexico, Albuquerque, NM, 1997
ACUTE EFFECT OF SIMULATED ALTITUDE

VENTILATION (L/min)

OXYGEN SATURATION (%)

*: p<0.05 or better, vs "baseline"
!: p<0.05, !!!: p<0.001 vs controls

Bernardi J.Hypertens 2001
confirmed in the field that yogic practitioners maintained similar oxygen levels as controls, but with significantly lower ventilation and lower resp. reflexes

Under extreme conditions, (climbing to Everest and K2), after 2wk acclimatisation, successful climbers (summiters without oxygen suppl) showed similar oxygenation, but lower resp. rate, lower ventilation and lower resp. reflexes.

*Bernardi et al, Eur Resp J, 2006*
• slow breathing proved very efficient at high altitude (Keyl, JAP 2003 Bernardi et al ERJ 2006, Eur J Appl Physiol 2007)

• “efficiency” of breathing seems more important than “quantity”

• More efficient breathing reduces the stimulus to ventilate

• and thus improves breathing reserve (essential or even vital in extreme conditions)
the LESS you can exercise!

the more your breathing is stimulated during exercise

Chua JACC 1997, Coats, BrHeart J, 2004

the LESS you can exercise!

some Resp Physiologists call VeVCO2: resp. EFFICIENCY!
after 1 month training (1h/day continuous or split), unlike ctl group, improvement in exercise capacity. all retained at 1 month after the end of training

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breaths/min</td>
<td>134±1.5</td>
<td>7.6±1.9*</td>
</tr>
<tr>
<td>SaO₂ %</td>
<td>925±0.3</td>
<td>932±0.4 *</td>
</tr>
<tr>
<td><strong>Exercise</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak VO₂ (ml/kmin)</td>
<td>139±0.8</td>
<td>159±0.8 *</td>
</tr>
<tr>
<td>Peak Load (watts)</td>
<td>92±6</td>
<td>100±4*</td>
</tr>
<tr>
<td>AT (watts)</td>
<td>598±3.7</td>
<td>648±4.3 *</td>
</tr>
<tr>
<td>Exercise time (sec)</td>
<td>422±22</td>
<td>615±18*</td>
</tr>
</tbody>
</table>

Bernardi et al., Lancet 1998
Slow breathing is often associated with meditation: spontaneous effect or teacher-guided?

EFFECT OF SHAVASANA ON RESPIRATORY RATE/BLOOD PRESSURE

Datey, Angiology, 1969

DM 58yr Essential Hypertension

Respiration

Before 22/min

During 8/min

MEAN BP: 134 107*

(N=10, *p<0.05)
BEFORE MEDITATION (BASELINE)

Padua, Italy, May 2016. Pictures taken while examining a yoga practitioner
BEFORE MEDITATION (BASELINE) ox.ssaturation and heart rate are normal

Padua, Italy, May 2016. Pictures taken while examining a yoga practitioner.
DURING MEDITATION...
DURING MEDITATION, ox.saturation low but heart rate stays normal (actually better!)
CONCLUSIONS

• meditation and breathing seems to act rather independently

• the ACUTE DROP in arterial oxygenation does NOT occur in the brain, and translates in a LONG-TERM INCREASE in arterial, cerebral and peripheral oxygenation and does not elicit a stress reaction

• Support the idea (Wallace, 1971) of hypometabolic state

• confirm resetting of chemoreflexes!

Bernardi NF, Psychophysiology, 2017
less need to breathe:

another major consequence:

readjustment of life-critical reflexes:

1) control of respiration
2) control of cardiovascular system
THE CARDIOVASCULAR AND RESPIRATORY SYSTEM ARE TIGHTLY CONNECTED

CONTROL OF THE HEART AND BLOOD VESSELS
heart rate
blood pressure...

CONTROL OF RESPIRATION
ventilation, blood gas exchange

THE LINK IS THE AUTONOMIC NERVOUS SYSTEM
(sympathetic and parasympathetic)
Reduced control of blood pressure
Low BAROreflex = increases in BP

In the long term: increased cardiovascular risk

Prolonged stress... hypertension, heart failure, COPD, metabolic syndrome, diabetes

High sympathetic

Low parasympathetic

High CHEMOreflex

High stimulation of breathing
Increased control of blood pressure = high BAROreflex = low CHEMOrereflex
Prevents increases in BP

(yoga, physical training…)

In the long term: Lowers BP, Relaxation, Red. Depression…
HOW SLOW BREATHING CAN AFFECT THE AUTONOMIC NERVOUS SYSTEM?

1) better oxygenation (and breathing efficiency) → reduce chemoreflex → reduce symp. activity

2) expansion of the lungs (~1L) directly stimulates the parasymp. system → reduces symp. activity

3) interference with the Mayer waves

4) central effect (relaxation) → reduces symp. activity
slow breathing interferes with the Mayer waves

normal breathing

slow breathing

heart period

respiration

systolic blood press.

diastolic blood press.

skin microcirculation

(time (approx 3min)

(2-11-1994: G.C. yoga teacher)
SLOW BREATHING AT THE RATE OF MAYER WAVES OF BLOOD PRESSURE

AVE MARIA

MANTRA

15/min BREATHING

RR INTERVAL (ms)

RESPIRATION (ml)

DIASTOLIC BLOOD PRESSURE (mmHg)

MID-CEREBRAL FLOW VELOCITY (cm/sec)

RR INTERVALS
OPPOSITE BEHAVIOR OF BARO- AND CHEMO-REFLEXES

BY EFFECT OF DIFFERENT BREATHING PATTERNS

Mason H. et al, EBCAM 2013
Carotid massage performed by Balinese islanders as therapy for insomnia (Schlager and Meier, 1947)

now many studies document positive psychological effects of yoga, (antidepressant, antistress…)

the relationship between carotid and mental states are well known even in the western culture:
carotid $\leftrightarrow$ κάρος = “sleep, numbness, deep relaxation!!! ”
now many studies document positive psychological effects of yoga, (antidepressant, antistress…)

Carotid massage performed by Balinese islanders as therapy for insomnia  (Schlager and Meier, 1947)

the relationship between carotid and mental states are well known even in the western culture: carotid ← κάρος = “sleep, numbness, deep relaxation!!! ”
Tonically overactive sympathetic nervous system & Reduced vagal activity

POTENTIAL VICIOUS CIRCLES OF REFLEX DERANGEMENTS IN IMPORTANT CARDIOVASCULAR DISEASES (eg: Heart failure, Hypertension, Chronic Obstr. Pulm. Dis…)

Francis & Coats, 2000

INCREASED BREATHING STIMULATION (Chemoreflex augmentation)

LOSS OF CARDIOVASC. CONTROL (Baroreflex attenuation)
Baroreflex sensitivity (ms/mmHg)

SLOW BREATHING
INCREASES BRS IN HEART FAILURE

Bernardi et al, Circulation 2002

AND REDUCES SYMP. NERVE TRAFFIC

Gosoh et al Circulation 2001
BAROREFLEX SENSITIVITY AND BREATHING RATE IN ESSENTIAL HYPERTENSION

Joseph et al. Hypertension 2005
COPD:

respiratory abnormalities
(hypoxia / hypercapnia)

chemoreflex activation

increased sympathetic activity

Heindl, AJRCCM 2001
Microneurography allows direct measurement of sympathetic nerve traffic.
Slow breathing reduces sympathetic activity and increases baroreflex sensitivity in BPCO

Spontaneous breathing 6/min

**BPCO subject**

SYMP. ➔

**control subject**

SYMP. ➔

Raupach et al, Eur Resp J, 2008
...BUT IS IT A GOOD IDEA TO INCREASE THE PARASYMPATHETIC TONE IN THE PRESENCE OF OBSTRUCTIVE PULMONARY DISEASES?
…BUT IS IT A GOOD IDEA TO INCREASE THE PARASYMPATHETHIC TONE IN THE PRESENCE OF OBSTRUCTIVE PULMONARY DISEASES?

here we have a paradox!
parasymp. activity is beneficial to the heart,
(it is one of the main goals of physical training)

BUT
it is known to induce bronchial constriction!
continuous measurement of bronchial area during different tests of parasympathetic stimulation


*Zannin et al, PlosOne, 2015*
direct (parasympathetic) stimulation of carotid baroreceptors at the neck

(neck suction)

-oxygen
-slow deep breathing
-direct barocept. stimulus
-metacholine

Zannin, PlosOne, 2015
we concluded:

parasympathetic activation, in itself, is apparently NOT beneficial to the lungs

however

when this effect is obtained with a deeper and slower breathing, the bronchodilator effect of the direct stretch of the lungs overrides the parasympathetically mediated (small) broncho-constriction!!!

this supports applications in asthma and chronic bronchitis

Zannin, PlosOne, 2015
less need to breath:

another major consequence:

readjustment of life-critical reflexes:

1) control of respiration
2) control of cardiovascular system

THE CASE OF DIABETES
Effect of 3-Month Yoga on Oxidative Stress in Type 2 Diabetes With or Without Complications

Hegde, et al, Diabetes Care 2011

123 T2DM Patients (aged 40-75yr) (60 intervention, 63 ctrls)
3day/wk for 3months
mostly asanas + 3 pranayams (time of practice not specified)

“Yoga practitioners achieved significant improvements in
BMI, Fasting Plasma Glucose, HbA1c, malondialdehyde, glutathione and vitamin C
at 3 months compared with the standard care group”

very important study
yoga works....why?
SLOW BREATHING and DIABETES

It is well known that glucose and oxygen metabolisms are strictly interrelated.

Diabetes = disturbed glucose metabolism
SLOW BREATHING and DIABETES

It is well known that glucose and oxygen metabolisms are strictly interrelated

Diabetes = disturbed glucose metabolism

...and oxygen?

their relationship in diabetes remains largely ignored

yet, diabetes has a major involvement of the autonomic nervous system, similar to what happens in hypoxia (sympathetic predominance, parasymp loss)
slow breathing increases Baroreflex sensitivity in Type 1 Diabetes
(= is autonomic dysfunction reversible? what is the cause?)

Rosengård-Bärlund et al. Diabetologia, 2009

[Graph showing baroreflex sensitivity vs. breathing rate for Healthy controls, T1DM, and Early Heart transplanted subjects]
OXYGEN INCREASES BAROREFLEX SENSITIVITY IN DIABETIC MORE THAN IN CONTROL SUBJECTS

= preexisting hypoxia?

Bernardi et al, Diabetologia 2011
Low oxygen saturation ($\text{SaO}_2$) is present at rest in Type1 Diabetes

<table>
<thead>
<tr>
<th>Healthy Controls</th>
<th>Type1 Diabetes</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=18</td>
<td>N=12</td>
</tr>
<tr>
<td>$\text{SaO}_2$ (%)</td>
<td>99 ±1 vs 97 ± 2</td>
</tr>
</tbody>
</table>

*Wheatley et al Eur J Appl Physiol, 2011*

<table>
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<tbody>
<tr>
<td>N=49</td>
<td>N=98</td>
</tr>
<tr>
<td>$\text{SaO}_2$ (%)</td>
<td>97.7 ±0.1 vs 97.2 ± 0.1</td>
</tr>
</tbody>
</table>

OXYGEN SATURATION: marked increase with $O_2$ and SLB

T1 diabetes

 baseline $\rightarrow$ SLB $\rightarrow$ SLB+O$_2$ $\rightarrow$ $O_2$ $\rightarrow$ baseline

p < 0.0001

baseline $\rightarrow$ SLB $\rightarrow$ SLB+O$_2$ $\rightarrow$ $O_2$ $\rightarrow$ baseline

p < 0.0001

CTL

 baseline $\rightarrow$ SLB $\rightarrow$ SLB+O$_2$ $\rightarrow$ $O_2$ $\rightarrow$ baseline

p < 0.0001

baseline $\rightarrow$ SLB $\rightarrow$ SLB+O$_2$ $\rightarrow$ $O_2$ $\rightarrow$ baseline

p < 0.0001

both Oxygen and slow breathing increased baroreflex in T1 diabetes

**SIMILAR EFFECTS?**

BLOOD PRESS. (diast) : increased markedly with $O_2$, decreased with SLB $\rightarrow$ SLB counteracted the effect of $O_2$


![Graph showing blood pressure changes with SLB and O2]
ARTERIAL STIFFNESS (AUGMENTATION INDEX 75): worsened markedly with $O_2$ and improved markedly with SLB
$\rightarrow$ SLB completely blocked the effect of $O_2$

ARTERIAL STIFFNESS (PULSE WAVE VELOCITY): worsened markedly with $O_2$ and improved markedly with SLB

$\Rightarrow$ SLB completely blocked the negative effect of $O_2$

if Oxygen is an irritative stimulus on the arteries, due to an excess in ROS, then the positive effect of slow breathing

IMPLIES THAT SLOW BREATHING COULD HAVE SOME (DIRECT OR INDIRECT) ANTIOXIDANT EFFECT
Electrical vagal stimulation:

_ Decreases the release of various cytokines (TNF-α, IL-6).
  Gupta RC. J Am Coll Cardiol, 2006

_ Inhibits the formation of reactive oxygen species.
THE MAIN CHRONIC DISEASES ARE STRICTLY INTERRELATED and self perpetuate in a vicious circle.
Reduced Cardiac Output  
Tissue hypoxia

Inflammation  
ROS accumulation

Insulin Resistance

Immobilization  
Deconditioning

autonomic changes
• Increased sympathetic
• Increased chemoreflex
• Overventilation
• Depressed baroreflex (HRV)

Skeletal muscle changes

Structural changes
• Progressive loss of muscle bulk

Metabolic changes
• Impaired oxidative metabolism
• Increased inflammation

Functional changes
• Reduced exercise tolerance
• Increased fatigability

cardiac dis.

Pulm. dis.

diabetes, obesity

SLOW BREATHING COULD HELP WAKENING/BREAKING THIS VICIOUS CIRCLE
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Tuula Soppela
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Nadja Vuori

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Emma Fagerholm
Stephanie Hägg

Helsinki University Central Hospital
Folkhälsan Research Center
SLOW BREATHING
so simple – so complex

Star of the hero, N. Rerich (1932)
SLOW BREATHING
so simple – so complex

...so wonderful!