



Chronic hyperventilation syndrome  
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By Patrick McKeown

# CHVS- Long history

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- ▶ Da Costa (1871) “Irritable heart”
- ▶ Kerr & colleagues (1937) “Hyperventilation syndrome”
- ▶ Soley & Shock (1938) discovered HVPT could reproduce symptoms
- ▶ Sir Thomas Lewis (1940) “Soldiers heart” & “Effort syndrome”
- ▶ Konstantin Buteyko (1957) “Disease of deep breathing”
- ▶ Claude Lum (1977) Papworth Method
- ▶ Perera (1988) Designer jeans syndrome
- ▶ Gulf war syndrome, Balkan war syndrome



# Chronic hyperventilation syndrome

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American Civil War, military physicians seeing soldiers under the stress of combat described a syndrome characterized by breathlessness, light headedness or dizziness, pronounced fatigue and exercise intolerance, numbness and paraesthesiae and chest pain.

Magarian G J, Middaugh DA, Linz DH: Hyperventilation syndrome: A diagnosis begging for recognition



# Chronic hyperventilation syndrome

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Hyperventilation occurs in many persons under stresses of daily living. It is manifest not only in those overtly stressed, anxious and depressed but also in those who appear outwardly calm as they "bottle up" their feelings, often because of undeveloped or lack of acceptable emotional outlets.

Magarian G J, Middaugh DA, Linz DH: Hyperventilation syndrome: A diagnosis begging for recognition



# Chronic hyperventilation syndrome

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Physicians and lay persons alike readily recognize acute hyperventilatory attacks occurring under acute stress. However, chronic or recurrent hyperventilation problems often are unrecognized.

Magarian G J, Middaugh DA, Linz DH: Hyperventilation syndrome: A diagnosis begging for recognition



# Chronic hyperventilation syndrome

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Commonly go undiagnosed for years (Fat Folder syndrome) and may be subjected to extravagant and prolonged investigations for non-existent specific disease. Large numbers grow frustrated and drift away from conventional medicine.

Jenny C King Hyperventilation-a therapist's point of view: discussion paper



# Chronic hyperventilation syndrome

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Lum 1977 writes: Some forty years ago Kerr, Dalton and Glibe wrote “Patients presenting the well known pattern of symptoms haunt the offices of physicians and specialists in every field of medical practice. They are often shunted from one physician to another, and the sins of commission inflicted upon them fill many black pages in our book of achievement.”

Lum Lc. Hyperventilation: the tip and the iceberg

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# Chronic hyperventilation syndrome

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Hyperventilation is a common feature of many acute clinical conditions that can be benign or potentially catastrophic. The symptoms accompanying hyperventilation are diverse and non-specific, reflecting a physiologic state of hypocapnia secondary to alveolar overventilation.

- ▶ Results of arterial blood gas analysis confirm hypocapnia.
- ▶ Hanashiro PK. Hyperventilation: benign symptom or harbinger of catastrophe? *Postgrad Med* 1990;88:191-3, 196.



## PaCO<sub>2</sub> as a predictor of mortality

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- ▶ A review of randomly selected hospital records of 114 patients, defined four groups based upon arterial carbon dioxide tension (PaCO<sub>2</sub>) and mode of ventilation.
- ▶ Group 1, with a PaCO<sub>2</sub> of 15 mm Hg or less, consisted of 25 patients with an over-all mortality of 88 per cent.
- ▶ Group II, with a PaCO<sub>2</sub> of 20 to 25 mm Hg, consisted of 35 patients with a mortality of 77 per cent.
- ▶ Mazzara JT, Ayres SM, Grace WJ. Extreme hypocapnia in the critically ill patient. *Am J Med* 1974;56:450-6.



# PaCO<sub>2</sub> as a predictor of mortality

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- ▶ Group III, with a PaCO<sub>2</sub> of 25 to 30 mm Hg, consisted of 33 patients with a mortality of 73 per cent.
- ▶ Group IV, with a PaCO<sub>2</sub> of 35 to 45 mm Hg, consisted of 21 patients with a mortality of 29 per cent (p <0.001).
- ▶ Extreme hypocapnia in the critically ill patient has serious prognostic implications and is indicative of the severity of the underlying disease.
- ▶ Mazzara JT, Ayres SM, Grace WJ. Extreme hypocapnia in the critically ill patient. Am J Med 1974;56:450-6.



# Chronic hyperventilation syndrome

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- ▶ “As a common aspect of many acute disorders, hypocapnia may have a pathogenic role in the development of systemic diseases. Increasing evidence suggests that hypocapnia appears to induce substantial adverse physiological and medical effects.”
- ▶ Laffey, J. & Kavanagh, B. Hypocapnia, *New England Journal of Medicine*. 4 July 2002.



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What drives our breathing, oxygen or carbon dioxide?

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What drives our breathing, oxygen or carbon dioxide?

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There is a large reserve of oxygen in the blood stream, such that oxygen levels must drop from 100mmHg to about 50mmHg before the brain stimulates breathing.



# Carbon dioxide drives our breathing

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The primary stimulus to breathe is the concentration of carbon dioxide in arterial blood which is detected by chemoreceptors within the arteries.

Advanced environmental exercise physiology By Stephen S. Cheung



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Carbon dioxide is generated as an end product from aerobic metabolism. It is created by the mitochondria within cells. An increase in metabolic activity such as physical exercise produces more carbon dioxide.

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# Primary regulator of pH

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Normal pH is 7.365 which must remain within tightly defined parameters. If pH is too acidic and drops below 6.8, or too alkaline rising above 7.8, death can result.

Blood, Sweat, and Buffers: pH Regulation During Exercise Acid-Base Equilibria  
Experiment Authors: Rachel Casiday and Regina Frey



# Bicarbonate buffer

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Carbon dioxide forms bicarbonate through the following reaction:



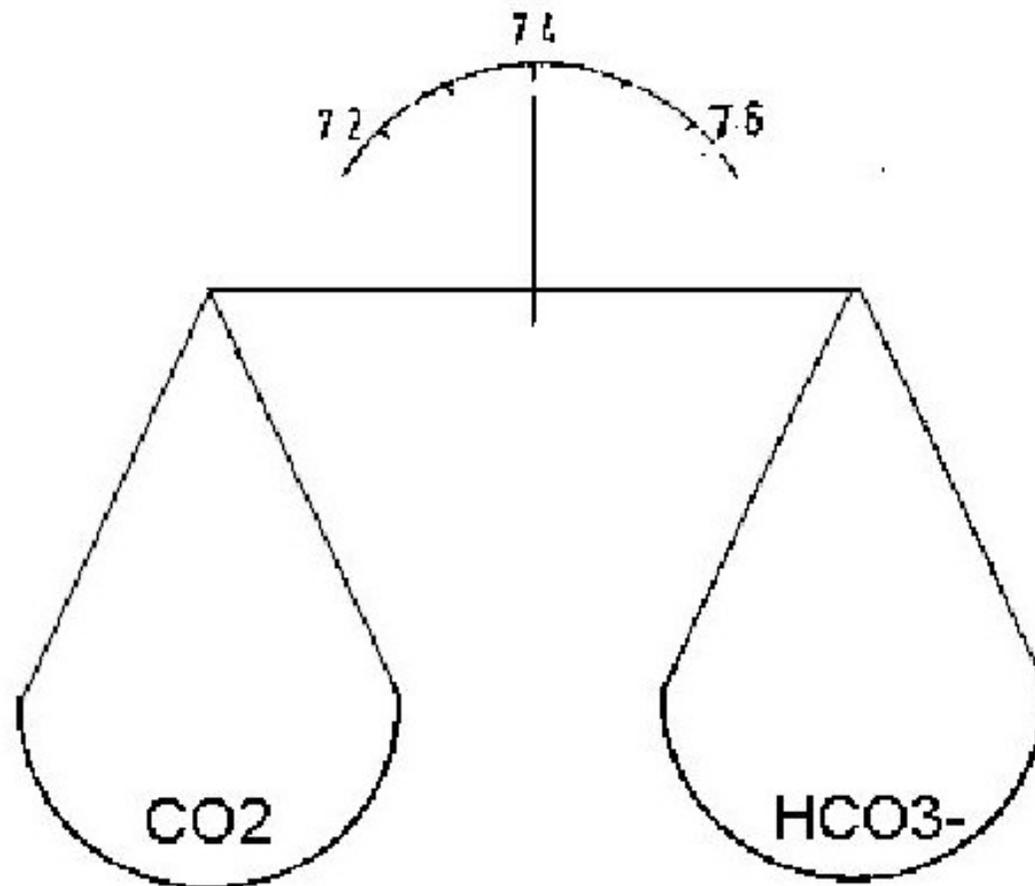
CO<sub>2</sub> disassociates into H<sup>+</sup> and HCO<sub>3</sub><sup>-</sup> constituting a major alkaline buffer which resists changes in acidity

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# pH

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# pH

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If you offload carbon dioxide, you are left with an excess of bicarbonate ion and a deficiency of hydrogen ion.

During short term hyperventilation-breathing volume subsequently decreases to allow accumulation of carbon dioxide and normalisation of pH.



# pH

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However, when overbreathing continues for hours/days, bicarbonate excess is compensated by renal excretion.

Hypocapnia and pH shift are almost immediate; adjustment of bicarbonate takes time. (hours to days)

Lum Lc. Hyperventilation: the tip and the iceberg

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# Hyperventilation becomes chronic

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Thus the chronic hyperventilator's pH regulation is finely balanced: diminished acid (the consequence of hyperventilation) is balanced against the low level of blood bicarbonate maintained by renal excretion.

Jenny C King Hyperventilation-a therapist's point of view: discussion paper



# Hyperventilation becomes chronic

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In this equilibrium small amounts of overbreathing induced by emotion can cause large falls of carbon dioxide and, consequently, more severe symptoms.

Jenny C King Hyperventilation-a therapist's point of view: discussion paper



# Effects of hypocapnia

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- ▶ Left shift of the oxyhaemoglobin curve (Bohr effect)
- ▶ Reduction of cerebral blood flow- anxiety, panic, phobias, irritability, poor concentration, fatigue (J.WASSERMAN & PATTERSON 1961)
- ▶ Increase brain lactate -anxiety neurosis (van Hulst RA et al 2004)



# Effects of hypocapnia

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- ▶ Neuronal hyperexcitability – numbness and tingling (Laffey et al 2002)
- ▶ Hyperexcitability of cardiac muscle fibers- atrial cardiac arrhythmias (Atlee JL 3rd, 1981)
- ▶ Reduced coronary blood flow with myocardial hypoxia (Masui. 1991 )
- ▶ Bronchospasm (Ritz T et al, 2008)



# Effects of hypocapnia

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Angina pectoris with or without angio graphic abnormality, vasomotor instability, chest pain, syncope/fainting and tachyarrhythmia, hypoglycaemia, hiatus hernia, irritable bowel, disorders of immunity, migraine, multiple sclerosis, Neurological disorders with paraesthesiae, tinnitus and musculoskeletal aches and pains, anxiety states, phobic disorders, panic attacks, asthma, myalgia.

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# Bohr effect

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Discovered in 1904 by the Danish physiologist Christian Bohr (father of Niels Bohr). The Bohr effect is the name of the law which describes the release of oxygen from hemoglobin.



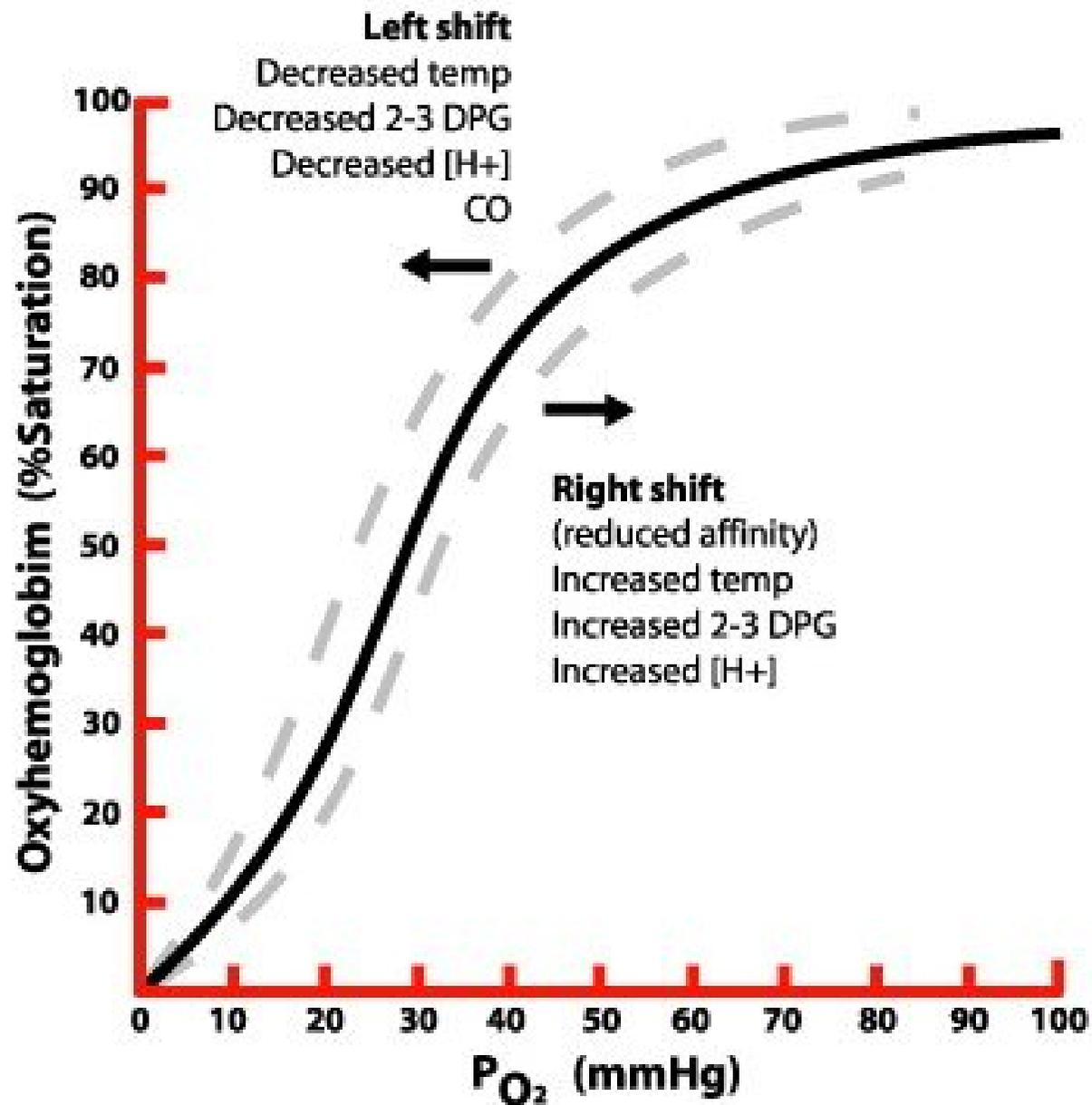
# Bohr effect

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In the words of Christian Bohr; “The carbon dioxide pressure of the blood is therefore to be regarded as an important factor in the inner respiratory metabolism. If one uses carbon dioxide in appropriate amounts, the oxygen uptake of the lungs will not be influenced, whereas the oxygen, that was taken up can be used more effectively throughout the body.”

Bohr; Hasselbalch, Krogh. 1904 Concerning a Biologically Important Relationship - The Influence of the Carbon Dioxide Content of Blood on its Oxygen Binding.





# Oxygen dissociation curve

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An exercising muscle has a greater requirement for oxygen than a resting one and this is facilitated by its chemical nature; “an exercising muscle is hot and generates carbon dioxide and it benefits from increased unloading of o<sub>2</sub> from its capillaries.”

West J 1995 Respiratory Physiology: the essentials. Lippincott, Williams and Wilkins.



# Effects of hypocapnia- pilots

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- ▶ We have no way of knowing how often symptoms of hyperventilation have troubled pilots of airplanes who did not survive the experience. Experienced pilots of airliners who have hundreds of hours of flying experience have admitted genuine fear, even panic when flying under unusually hazardous conditions. If fear can produce hyperventilation, the resultant symptoms appear to interfere seriously with skilful handling of the controls.

- ▶ The syndrome of hyperventilation: its importance in aviation. HC Hinshaw
- 



# Effects of hypocapnia- sleep quality

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- ▶ When mechanical hyperventilation lowered the CO<sub>2</sub> to 85%, 75%, and 65% of normal, rapid eye movement sleep decreased progressively from a control level of 17% of total recording time to 12%, 7%, and 4%, respectively.
- ▶ Hypocapnia Decreases the Amount of Rapid Eye Movement Sleep in Cats
- ▶ Andrew T. Lovering, PhD; Jimmy J. Fraigne, BS; Witali L. Dunin-Barkowski PhD, D.Sc; Edward H. Vidruk PhD; John M. Orem PhD



# Effects of hypocapnia- cardio

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PCO<sub>2</sub> (or respiratory alterations of pH) may have a direct effect on the regulation of coronary blood flow. The low coronary sinus PO<sub>2</sub> observed at hypocapnia may suggest the risk of myocardial ischaemia (reduced blood flow).

[Bull Eur Physiopathol Respir.](#) 1979 Jul-Aug;15(4):625-38. Effect of CO<sub>2</sub> on the systemic and coronary circulations and on coronary sinus blood gas tensions. [Foëx P](#), [Ryder WA](#).

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## Effects of hypocapnia - cardio

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Hypocapnic hyperventilation (PaCO<sub>2</sub>: 22 mmHg) invariably resulted in a significant reduction of coronary blood flow (LADBF) and left ventricular myocardial tissue PO<sub>2</sub> in both epicardial and endocardial layers, while addition of carbon dioxide to the inspired gas (hypercapnic hyperventilation) reversed the change.

[Masui](#). 1991 Nov;40(11):1620-4. [**Effect of arterial carbon dioxide tension on regional myocardial tissue oxygen tension in the dog**].  
[Okazaki K](#), [Hashimoto K](#), [Okutsu Y](#), [Okumura F](#)

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## Effects of hypocapnia - cardio

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There is substantial evidence that hyperventilation can provoke coronary vasospasm. Individuals with Prinzmetal's angina appear to be more susceptible to hyperventilation-induced myocardial ischemia. Efforts to terminate hyperventilation such as sedation, reassurance, rebreathing and instruction in relaxation techniques should be utilized.

Chest. 1988 May;93(5):1095-6. **Hyperventilation and myocardial infarction.** Chelmowski MK, Keelan MH Jr.

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# Effects of hypocapnia - cardio

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Thirteen patients with ischemic coronary heart disease purposely hyperventilated for seven minutes in order to induce hypocapnic alkalosis.

Hypocapnic alkalosis due to hyperventilation interferes with myocardial O<sub>2</sub> supply by

- 1) coronary vasoconstriction and
- 2) increased O<sub>2</sub> affinity of blood.

[Circulation](#). 1975 Nov;52(5):854-8. Impairment of myocardial O<sub>2</sub> supply due to hyperventilation. [Neill WA](#), [Hattenhauer M](#).

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## Effects of hypocapnia- calcium

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- ▶ Hyperventilation-induced alkalosis resulted in marked decreases in total calcium, phosphorus, and ionized calcium.

Crit Care Med. 1984 Dec;12(12):1055-6. Effect of hyperventilation on total calcium, ionized calcium, and serum phosphorus in neonates. Watchko J, Bifano EM, Bergstrom WH.



# Effects of hypocapnia- calcium

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- ▶ When blood becomes alkalotic, bound hydrogen ions dissociate from albumin, (protein in blood plasma) freeing up the albumin to bind with more calcium and thereby decreasing the freely ionized portion of total serum calcium. For every 0.1 increase in pH, ionized calcium decreases by about 0.05 mmol/L.
- ▶ Nephrol Dial Transplant (2005) 20: M. G. Zeier) Seizures and renal failure: is there a link?



# Effects of hypocapnia- calcium

## Chickens Drink Fizzing Water

URBANA, Ill. (AP) — In the hen houses of the University of Illinois, it goes like this: fizz, fizz, plop, plop.

These chickens are drinking carbonated water and then laying better eggs. Scientists found that the bubbly water sets up a chemical chain reaction that makes more calcium available for eggshell production.

The result, said researcher Ted Odom, is stronger eggshells.

"When they drink the carbonated water, the amount of breakage is significantly reduced," said Odom.

The money that egg producers can save by reducing breakage should more than offset the cost of carbonating water, said Odom, but he said specific economic studies will be done later.

For years, scientists have been looking for a solution to the soft-shelled, easily broken eggs which are laid during hot weather.

Chickens cool themselves by panting, but the panting also changes their blood chemistry. Carbonate is lost

for eggshell production, Odom said.

Using carbonated water to replace carbon dioxide lost during panting seems to reverse the process. And Odom said the chickens like bubbly water just as well as the regular stuff.

Odom, working under the direction of animal scientist Paul Harrison, examined the effects of carbonated water on eggs laid by more than 400 chickens. They were compared with the eggs of an equal number of chickens given plain water.

He found that during hot periods chickens on normal water produced eggs that were a little more than 8 percent shell. Chickens on carbonated water produced eggs that were nearly 9 percent shell.

"That is significant," he said. "There is a very fine line between the point when an egg doesn't break and when it does break."

Odom said there were no other important changes as a result of using the carbonated water; "They laid the same number of eggs, and the size of the eggs was the same."

[s.google.com/nwshp](https://www.google.com/nwshp) cium is available



# Effects of hypocapnia- calcium

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- ▶ A carbonated drinking water system was installed in a cage layer facility and its effects on performance of 46- and 86-wk old commercial laying hens was evaluated during a 12-wk period in the summer. Overall, egg specific gravity (Weeks 1-12) of eggs laid by older hens was improved ( $P \leq .06$ ) by providing a constant source of carbonated drinking water versus those given only tap drinking water (1.0790 versus 1.0776 g/cm<sup>3</sup>).

- ▶ Carbonated Drinking Water for Improvement of Eggshell Quality of Laying Hens During Summertime Months [Ken W. Koelkebeck](#), [Paul C. Harrison](#) and [Carl M. Parsons](#)



# Effects of hypocapnia

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Symptoms may show up anywhere, in any organ, in any system; for we are dealing with a profound biochemical disturbance, which is as real as hypoglycemia, and more far-reaching in its effects.

Lum Lc. Hyperventilation: the tip and the iceberg

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## Relevance of breath hold time as a determinant of carbon dioxide tolerance

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During a breath hold, gas exchange is halted and carbon dioxide accumulates in the blood and lungs. As carbon dioxide is the primary stimulus to breathe, the length of breath hold time is influenced by tolerance or ventilatory response to carbon dioxide in the blood and lungs.



# The Control Pause

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- ▶ Holding of the breath after an exhalation until the first spasm of breathing muscles. If BHT is less than twenty seconds, main symptoms are present.
- ▶ If BHT is between twenty and forty seconds, main symptoms are gone, but trigger could produce symptoms.
- ▶ CP of forty seconds- no symptoms.



# Hyperventilation Provocation test

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Hyperventilation is a highly specific test for the diagnosis of coronary artery spasm, and that hyperventilation test-positive patients are likely to have life-threatening arrhythmias during attacks and multivessel spasm.

[Am J Cardiol.](#) 1997 Sep 1;80(5):545-9. **Hyperventilation as a specific test for diagnosis of coronary artery spasm.** [Nakao K](#), [Ohgushi M](#), [Yoshimura M](#), [Morooka K](#), [Okumura K](#), [Ogawa H](#), [Kugiyama K](#), [Oike Y](#), [Fujimoto K](#), [Yasue H](#).

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# Hyperventilation Provocation test

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The hyperventilation test can be recommended as the first test in the work up of suspected vasospastic angina pectoris.

- ▶ [Schweiz Med Wochenschr.](#) 1995 Apr 22;125(16):777-85. [Hyperventilation test: a noninvasive screening test for coronary vasospasm]. [Article in German] [Mang G](#), [Schuiki E](#), [Amann FW](#).



# Breathing retraining- cardiac

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- ▶ Subjects evidenced significantly higher end-tidal carbon dioxide levels and lower respiratory rates when compared to pretreatment levels measured three years earlier. Subjects also continued to report a decrease in the frequency of functional cardiac symptoms when compared to pretreatment levels.

Biofeedback Self Regul. 1996 Jun;21(2):191-8. Breathing retraining: a three-year follow-up study of treatment for hyperventilation syndrome and associated functional cardiac symptoms. DeGuire S, Gevirtz R, Hawkinson D, Dixon K.



# Breathing retraining- cardiac

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- ▶ Results demonstrated that all 3 methods of breathing retraining were equally effective in modifying respiratory physiology and reducing the frequency of functional cardiac symptoms. Results determined that respiratory rate and subject's perception that training had generalized were the best predictors of treatment success.
- ▶ [Am J Cardiol.](#) 1992 Sep 1;70(6):673-7. Hyperventilation syndrome and the assessment of treatment for functional cardiac symptoms. [DeGuire S](#), [Gevirtz R](#), [Kawahara Y](#), [Maguire W](#).



# Breathing retraining- asthma

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4-week training aimed at normalizing basal and acute levels of end-tidal carbon dioxide. Basal levels of PCO<sub>2</sub> increased from hypocapnic to normocapnic range. Improvements were accompanied by improvements in lung function and reductions in diurnal lung function variability. Improvements remained stable throughout follow-up.

- ▶ [Appl Psychophysiol Biofeedback](#). 2012 Jan 1. **Hypoventilation Training for Asthma: A Case Illustration.** [Jeter AM](#), [Kim HC](#), [Simon E](#), [Ritz T](#), [Meuret AE](#).



# That's all folks!

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