INTRODUCTION

• During hyperpnea (increased depth of breathing), the relative cost of breathing increases exponentially when moving from moderate exercise to heavy and maximal exercise levels.

INTRODUCTION

• While at moderate exercise, the cost of the respiratory system accounts for 3-6% total VO2max, heavy exercise accounts for a ~10% demand and maximal exercise accounts for anywhere between 13-15%.

INTRODUCTION

• Breathing efficiency and physical fitness are both independent and complementary; while physical fitness does not always translate into breathing efficiency, there is no doubt that breathing efficiency is the gateway to attaining physical fitness.
HOW SHOULD WE BREATHE?

• Breathing is light, quiet, effortless, soft, through the nose, diaphragmatic, rhythmic and gently paused on the exhale.

• This is how human beings breathed until the comforts of modern life changed everything, including our breathing.
How to Measure Breathlessness
“Generally speaking, there are three levels of breathing. The first one is to breathe SOFTLY, so that a person standing next to you does not hear you breathing. The second level is to breathe softly so that YOU do not hear yourself breathing. And the third level is to breathe softly so that you do not FEEL yourself breathing.”

Chris Pei: Beginners guide to Qi Gong
• Professional Hatha yogi breathing just one gentle breath per minute for the duration of one hour.

HOW SHOULD WE BREATHE?

• 4 -6 liters of air per minute during rest

HOW TO MEASURE BREATHLESSNESS
BOLT (COMFORTABLE BREATH HOLD TIME) MEASUREMENT

• Take a small silent breath in through your nose.

• Allow a small silent breath out through your nose.

• Hold your nose with your fingers to prevent air from entering your lungs.

• Count the number of seconds until you feel the first distinct desire to breathe in.
BOLT (COMFORTABLE BREATH HOLD TIME) MEASUREMENT

Measuring How Big You Breathe

- Control Pause (CP)
- Breath In
- Breath Out
- Calm Breath In
- Comfortable Breath - HOLD
- First signs of air hunger
- Tummy may jump
HOW TO MEASURE BREATHLESSNESS

• Stanley et al. concluded that, ‘the breath hold time/partial pressure of carbon dioxide relationship provides a useful index of respiratory chemosensitivity’.

HOW TO MEASURE BREATHLESSNESS

• Breath holding as one of the most powerful methods to induce the sensation of breathlessness, and that the breath hold test ‘gives us much information on the onset and endurance of dyspnea.

HOW TO MEASURE BREATHLESSNESS

• Holding of the breath until the first definite desire to breathe is not influenced by training effect or behavioural characteristics, it can be deduced to be a more objective measurement of breathlessness.

HOW TO MEASURE BREATHLESSNESS

• Eighteen patients with varying stages of cystic fibrosis were studied to determine the value of the breath hold time as an index of exercise tolerance. The breath hold times of all patients were measured.

HOW TO MEASURE BREATHLESSNESS

• The researchers found a significant correlation between breath hold time and VO₂ (oxygen uptake).

HOW TO MEASURE BREATHLESSNESS

• ‘that the voluntary breath-hold time might be a useful index for prediction of the exercise tolerance of CF patients’.

HOW TO MEASURE BREATHLESSNESS

• Breath hold time varies inversely with the magnitude of dyspnea when it is present at rest.

“If a person breath holds after a normal exhalation, it takes approximately 40 seconds before the urge to breathe increases enough to initiate inspiration.”

HOW SHOULD WE BREATHE?

• When your breathing receptors have a strong response to carbon dioxide and reduced pressure of oxygen in the blood, your breathing will be intense and heavy.
HOW SHOULD WE BREATHE?

- During strenuous physical exercise, the consumption of oxygen increases, leading to a slightly reduced concentration of O2 in the blood. At the same time, increased muscle activity and metabolic rate produces more carbon dioxide, causing an increased concentration of CO2 in the blood.
HOW SHOULD WE BREATHE?

- The sensitivity of your receptors to carbon dioxide and oxygen will have implications for the way your body copes with physical exercise.
HOW SHOULD WE BREATHE?

- One difference between endurance athletes and non-athletes is decreased ventilatory responsiveness to hypoxia (low oxygen) and hypercapnia (higher carbon dioxide).

HOW SHOULD WE BREATHE?

• The lighter breathing of the athlete group may explain the link between “low ventilatory chemosensitivity and outstanding endurance athletic performance.”

HOW SHOULD WE BREATHE?

• The lower ventilation in Trained Men than in Untrained Men, both at sea level and in hypoxia, was probably due to reduced chemoresponsiveness. A weaker hypercapnic ventilatory responsiveness may reduce ventilation in trained men.

EFFECT ON VO_{2 \text{ MAX}}
EFFECT ON VO2 MAX

• The maximum capacity of your body to transport and utilise oxygen in one minute during maximal exercise.
EFFECT ON VO2 MAX

• The athletes’ response to increased carbon dioxide was 47% of that recorded by the non-athlete controls. Athletic ability to perform during lower oxygen pressure and higher carbon dioxide pressure, corresponded to maximal oxygen uptake or VO2 max.

EFFECT ON VO2 MAX

• CO2 responsiveness was found to correlate negatively with maximum oxygen uptake in four out of the five trained subjects.

TRAINING METHODS
OXYGEN CARRYING CAPACITY

• Blood is made up of three parts: oxygen-carrying red cells, white blood cells and plasma.

• Hemoglobin is a protein found within the red cells.
**OXYGEN CARRYING CAPACITY**

- Hematocrit refers to the percentage of red blood cells in the blood. Under normal conditions, hematocrit will relate closely to the concentration of hemoglobin in the blood. Hematocrit is usually found to be 40.7- 50% for males and 36.1- 44.3% for females.
OXYGEN CARRYING CAPACITY

• Performance improves with an increase in hemoglobin and hematocrit, which increases oxygen carrying capacity of the blood thus improving aerobic ability.

HIGH ALTITUDE TRAINING

- To limit the detraining effects of working at high altitude while still maintaining the benefits, Dr Levine and James Stray Gundersen from the University of Texas in Dallas developed the 'live high and train low' model in the 1990s.
HIGH ALTITUDE TRAINING

• The premise of the method is to enable athletes to benefit from the positive physiological changes associated with living at a high altitude while enabling them to train at their maximum work rate.
HIGH ALTITUDE TRAINING

• A study of 39 male and female collegiate distance runners who were evenly matched in fitness level.

• Results for the 'live high and train low' group showed a 9% improvement in red blood cell volume and a 5% improvement in maximal oxygen uptake (VO₂ max).

• Stray-Gundersen J, Chapman RF, Levine BD. "Living high-training low" altitude training improves sea level performance in male and female elite runners. Journal of Applied Physiology. 2001;(Sep;91(3)):1113-20
TRAINING METHODS

• The improvement in maximal oxygen uptake was in direct proportion to increased red cell mass volume. This translated to an impressive performance improvement of 13.4 seconds in a 5,000 metre run.

• Stray-Gundersen J, Chapman RF, Levine BD. "Living high-training low" altitude training improves sea level performance in male and female elite runners. Journal of Applied Physiology. 2001;(Sep;91(3):):1113-20
HIGH-INTENSITY TRAINING

• Tabata training, where athletes give their full effort at an exhausting work rate for periods of just 20 seconds at a time.

HIGH-INTENSITY TRAINING

• Concluded that although moderate-intensity aerobic training improved aerobic power, high-intensity intermittent training improved both anaerobic and aerobic performance.

INTERMITTENT HYPOXIA TRAINING (IHT)
INTERMITTENT HYPOXIA TRAINING (IHT)

• Intermittent hypoxic interval training (IHIT) is defined as a method where during a single training session, there is alternation of hypoxia and normoxia.

INTERMITTENT HYPOXIA TRAINING (IHT)

• It is possible to get a significant arterial desaturation during exercise without being placed in an hypoxic environment.

INTERMITTENT HYPOXIA TRAINING (IHT)

- Repeatedly using breath holding following exhalation during training would represent an intermittent hypoxic exposure and could therefore be likened to IHT, although hypoventilation also induces hypercapnia.

INTERMITTENT HYPOXIA TRAINING (IHT)

• For hundreds of thousands of years, breath holding was extensively practised by our ancestors for the purposes of foraging for food,- might have been responsible for a number of unique human features.
INTERMITTENT HYPOXIA TRAINING (IHT)

- Breath-hold training causes lower blood acidity, higher tolerance to anoxia, decelerated metabolism and an increase in Hct value, Hb and EPO concentration as well as the mass and volume of the lungs.

INTERMITTENT HYPOXIA TRAINING (IHT)

• Not all researchers have reported improvements to aerobic capacity. More research is required.

• No change in Hb after training

Xavier Woorons, Pascal Mollard, Aurélien Pichon, Alain Duvallet, Jean-Paul Richalet, Christine Lamberto. Effects of a 4-week training with voluntary hypoventilation carried out at low pulmonary volumes. Respiratory Physiology & Neurobiology 160 (2008) 123–130
INTERMITTENT HYPOXIA TRAINING (IHT)

- For most people, after a week or so of practice, a drop of oxygen saturation below 90% can be observed – a level that is comparative to the effects of living at an altitude of 3,000-4,000 metres.
THE SPLEEN
THE SPLEEN

• The Spleen acts as a blood bank by absorbing excess volume and releasing stores during increased oxygen demands or decreased oxygen availability.

• Isbister JP. Physiology and pathophysiology of blood volume regulation. Transfus Sci. 1997;(Sep;18(3)):409-423
THE SPLEEN

• The spleen stores blood to a volume that may amount to about 200–300 ml, with 80% of the content consisting of hematocrite (Laub et al., 1993).

• *Journal of Human Kinetics* volume 32/2012, 197-210
THE SPLEEN

- During the breath-hold, the spleen contracts to the same extent, regardless of whether the diver is above or under water, pumping blood to the cardiac system, and with this, aggregated erythrocytes

- (Bakovic et al., 2005, Schagatay et al., 2007). Journal of Human Kinetics volume 32/2012, 197-210
THE SPLEEN

• The resultant blood oxygen capacity enables an increase in O2 concentration by 2.8–9.6% and more intense oxygen transport inter alia to the chest and other organs essential to breath-hold diving.

THE SPLEEN

• Spleen contraction develops quickly, as it occurs in the first repetition of the breath-hold, and after the next 3 to 4, it reaches its maximum and is very variable (20–46%) and depends on changes in the hypoxia rate

THE SPLEEN

• With every apnea the spleen contracts, releasing successive amounts of blood containing red blood cells.

• Journal of Human Kinetics volume 32/2012, 197-210
THE SPLEEN

• An additional number of erythrocytes circulating in blood due to spleen contraction may be equally important to the following: an increase of the O2 reserve and available O2 supply; an increase in CO2 buffering; simultaneous extension of the “easy phase”, and a delay of the unintentional respiratory movements characteristic of the “struggle phase”, or volitional prolongation of the apnea (Schagatay et al., 2005).

• Journal of Human Kinetics volume 32/2012, 197-210
THE SPLEEN

- Repeated, multiple breath hold dives intensify the spleen contraction effect. It shows that hypoxemia enhances spleen and kidney function, increasing Htc and Hb circulating in blood (Schagatay et al., 2007, De Bruijun et al., 2008).

- *Journal of Human Kinetics volume 32/2012, 197-210*
THE SPLEEN

- During breath holding, large amounts of erythrocytes are excreted from the spleen, which raises Hct and Hb concentration from 2 to 5% (Jelkmann, 1992).

- Journal of Human Kinetics volume 32/2012, 197-210
APNEIC SPLEEN CONTRACTION

• Five maximum breath holds with their face immersed in cold water, and each breath hold was separated by a two-minute rest- Spleen size decreased by 20%.

Researchers concluded that the "results show rapid, probably active contraction of the spleen in response to breath hold in humans."

APNEIC SPLEEN CONTRACTION

• Results showed a 6.4% increase in hematocrit (Hct) and a 3.3% increase in hemoglobin concentration (Hb) following five breath holds.

• Schagatay E, Andersson JP, Hallén M, Pålsson B. Selected contribution: role of spleen emptying in prolonging apneas in humans. Journal of Applied Physiology. 2001;(Apr;90(4)):1623-9
APNEIC SPLEEN CONTRACTION

• Significant splenic contraction has been found to take place with even very short breath holds of 30 seconds.

• However, the strongest contractions of the spleen are shown following maximum breath holds.

After the three breath holds, the increase in Hb in the hypercapnic (higher carbon dioxide) trial was 9.1% greater than in the normal carbon dioxide trial (normocapnic) and 71.1% greater than in the lower carbon dioxide trial (hypocapnic).

Richardson, Matt X. Hematological changes arising from spleen contraction during apnea and altitude in humans. Doctoral dissertation. 2008; (978-91-86073-03-9)
• Richardson concluded that "an increased capnic stimulus during breath hold may elicit a stronger spleen response and subsequent Hb increase than breath hold preceded by hyperventilation."

• Richardson, Matt X. Hematological changes arising from spleen contraction during apnea and altitude in humans. Doctoral dissertation. 2008; (978-91-86073-03-9)
EPO
The narrowing of the blood vessels, caused by the activation of the sympathetic nervous system during breath-hold diving, causes decreased blood circulation to organs that are more resistant to anoxia, especially the extremities, and to the decrease in PO2 in pulmonary alveola and in arterial blood (Fagius and Sundlof, 1986).

Journal of Human Kinetics volume 32/2012, 197-210
• As a result of decreased blood perfusion, local ischaemia occurs in the kidneys, causing anoxia, which also stimulates EPO production (Balestra et al., 2006). EPO stimulates proliferation and maturation of bone marrow’s red blood cells.

• *Journal of Human Kinetics* volume 32/2012, 197-210
Intensive breath-hold diving training (e.g. 5–6 h a day, 6 days a week for 6 months) sufficiently stimulates EPO increase, which causes higher red blood cells concentration and greater abilities to hold one’s breath for longer periods of time (Lemaître, 2009).

- Journal of Human Kinetics volume 32/2012, 197-210
BREATH HOLDING INCREASES EPO

• Results showed that EPO concentration increased by 24%, which peaked at three hours after the final breath hold and returned to baseline two hours later.

• (Three sets of five maximum duration breath holds, with each set separated by ten minutes of rest.) de Bruijn R, Richardson M, Schagatay E. Increased erythropoietin concentration after repeated apneas in humans. Eur J Appl Physiol 2008;102:609–13.
BREATH HOLDING INCREASES EPO

• Results showed a 20% increase to EPO in patients with severe obstructive sleep apnea, which decreased following CPAP.

BREATH HOLDING INCREASES EPO

- Apnoea should be used directly before a race because its effects (i.e. increased Hct) disappear in 10 minutes after the last apnoea.

HYPERCAPNIC-HYPOXIC TRAINING
HYPERCAPNIC- HYPOXIC TRAINING

• Research to establish the effects of 8 week hypercapnic-hypoxic training program in elite male swimmers, 30 to 45 minutes, three times a week.

HYPERCAPNIC- HYPOXIC TRAINING

• Each test subject has withheld breath individually, by a subjective feeling, for as long as possible.

HYPERCAPNIC- HYPOXIC TRAINING

• The condition is that each breath hold must be above the minimum values which describe hypercapnia, that is, the values of carbon dioxide in the exhaled breath had to be over 45 mmHg, which was controlled by a capnometer.

HYPERCAPNIC- HYPOXIC TRAINING

• Besides the swimming training sessions the control group was subjected to additional aerobic training sessions on a treadmill. The program was conducted three times a week for eight weeks.

HYPERCAPNIC- HYPOXIC TRAINING

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<thead>
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<th>Experiment</th>
<th>Control</th>
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<tr>
<td>Pre: Hb (g/L)</td>
<td>144.63</td>
<td>147.75</td>
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<tr>
<td>Post: Hb (g/L)</td>
<td>152.38</td>
<td>145.38</td>
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5.35% higher Hb

## HYPERCAPNIC- HYPOXIC TRAINING

<table>
<thead>
<tr>
<th></th>
<th>Experiment</th>
<th></th>
<th>Control</th>
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<tbody>
<tr>
<td>VO2 Max Pre</td>
<td>63.80</td>
<td></td>
<td>59.46</td>
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<tr>
<td>VO2 Max Post</td>
<td>70.38</td>
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<td>60.81</td>
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</table>

10.79% increase to VO2 max

HYPERCAPNIC- HYPOXIC TRAINING

- 15 middle distance runners
- (600- 3000m) over six weeks
- Runners participated in official athletics competition before and after

Fortier E, Nadeau. Peterborough, Canada
HYPERCAPNIC- HYPOXIC TRAINING

• First group- normal breathing +.03% improvement

• Fortier E, Nadeau. Peterborough, Canada
HYPERCAPNIC- HYPOXIC TRAINING

• Second group- 15 to 20 minutes of breath holding on the exhalation once per week: +1.27% improvement

• Third group- 15 to 20 minutes of breath holding on the exhalation twice per week: +1.33% improvement

*Fortier E, Nadeau. Peterborough, Canada*
HYPERCAPNIC- HYPOXIC TRAINING

• Runners trained 3 times per week with VHL over a 4 week period

• Lactic threshold, (the intensity of exercise at which lactate begins to accumulate in the blood at a faster rate than it can be removed) did not change

• 85% of the runners who applied VHL improved their maximum velocity attained at the end of a treadmill test by .5km/h on average.

• Mean improvement of VHL group: + 2.4%

• Normal breathing group- no change

• Woorons X. Effects of 4 week training with voluntary hypoventilation carried out at low pulmonary volumes.
HYPERCAPNIC- HYPOXIC TRAINING

• Over a 5-week period, sixteen triathletes (12 men, 4 women) were asked to include twice a week into their usual swimming session one with hypoventilation at low lung volume (VHL group) or with normal breathing (CONT group).

HYPERCAPNIC- HYPOXIC TRAINING

• Before (Pre-) and after (Post-) training, all triathletes performed all-out front crawl trials over 100, 200 and 400m.

HYPERCAPNIC- HYPOXIC TRAINING

• Time performance was significantly improved in trials involving breath holding following an exhalation in all trials but did not change in CONTROLS.

• [100m: – 3.7 ± 3.7s

• 200m: – 6.9 ± 5.0s

• 400m: – 13.6 ± 6.1s

LONG TERM EFFECTS
LONG TERM EFFECTS OF BREATH HOLDING

• Resting Hb mass in trained breath hold divers was 5% higher than untrained. In addition breath hold divers showed a larger relative increase to Hb after three apneas.

LONG TERM EFFECTS OF BREATH HOLDING

• Pre-test hemoglobin tended to be higher in the diver group than both skiers and untrained. (divers 150.1 g/L; skiers 145.5 g/L; untrained 146.9 g/L)

EFFECT ON RUNNING ECONOMY
EFFECT ON RUNNING ECONOMY

• The amount of energy or oxygen consumed while running at a speed that is less than maximum pace. Typically, the less energy required to run at a given pace, the better – if your body is able to use oxygen efficiently, it is indicative of a high running economy.
• Running economy has been linked to success in distance running, such that faster runners are more economical (Morgan et al., 1995; Lavin et al., 2012) and better metabolic efficiency preserves glycogen and delays the onset of fatigue (Rapoport, 2010).

EFFECT ON RUNNING ECONOMY

- Eighteen swimmers comprising of ten men and eight women who were assigned to two groups. The first group was required to take only two breaths per length and the second group seven breaths.

EFFECT ON RUNNING ECONOMY

• Researchers found that running economy improved by 6% in the group that performed reduced breathing during swimming.

ACIDOSIS
REDUCED ACIDOSIS

- Fatigue- physiological- breaking point at which the athlete cannot continue exercise intensity.
REDUCED ACIDOSIS

• Delaying fatigue is important in sports requiring anaerobic performance.
REDUCED ACIDOSIS

- Metabolism produces CO2 - dissociates to H+ and HCO₃⁻
- Sufficient oxygen to the muscles - H+ is oxidised in the mitochondria to generate water
- Insufficient oxygen - all H+ cannot be oxidised and associates with pyruvic acid to form lactic acid
REDUCED ACIDOSIS

• Breath holding after an exhalation causes a decrease to the concentration of oxygen to trigger increased lactic acid.

• At the same time, carbon dioxide also increases leading to an increased concentration of hydrogen ions to further acidify the blood.
REDUCED ACIDOSIS

• Increased carbon dioxide: Increased H+ and HCO3-

• Repeated exposure to increased acidosis- forces the body to adapt to it.

• To neutralise H+, buffering capacity improves
REDUCED ACIDOSIS

• Main Buffering:

• Blood- Haemoglobin and bicarbonate

• Skeletal muscle- proteins, phosphates (60%) and to a lesser extent bicarbonate (18%)

• Possibly, enhanced buffering capacity in muscle compartments- lowering diffusion of H+ to the blood.

• Woorons X
REDUCED ACIDOSIS- HOW?

• Central Governor theory- the brain protects the body against the risks from extreme exertion. At some point, the brain tells the working muscles to stop or slow down. Fatigue is not just physical but also psychological phenomenon - to maintain homeostasis.

• Woorons X
REduced ACIDOSIS - How?

• Acidosis impairs homeostasis. Breath holding conditions the brain to tolerate strong acidosis - teaches the brain that the body can go harder and faster without over doing it.

• Woorons X
INCREASED LACTATE

• In breath holding following an exhalation, maximal lactate concentration (+ 2.35 ± 1.3 mmol.L-1 on average) and the rate of lactate accumulation in blood (+ 41.7 ± 39.4%) were higher at Post- than at Pre- in the three trials whereas they remained unchanged in CONTROLS.

INCREASED LACTATE

- Increased Lactate max reflects an improved anaerobic capacity and may be due to a greater ability to tolerate high concentrations of lactate and high level of acidosis, as reported after high-intensity training.

ANEROBIC TRAINING

- It can be traumatizing to repeatedly perform exercises at high intensities to stimulate an anaerobic state.
- Training at a moderate intensity with breath holding could reduce the risk of injury.
The precise mechanisms explaining breath-holding and causing the breath at breakpoint are unknown. There are several useful reviews (Mithoefer, 1965; Godfrey & Campbell, 1968, 1969; Porter, 1970; Campbell & Guz, 1981; Lin, 1982; Nunn, 1987).

Breath holding breakpoint

- During breath-holding, the arterial or end tidal partial pressure of oxygen falls below its normal level of ~100 mmHg and that of carbon dioxide rises above its normal level of ~40 mmHg.

BREATH HOLDING BREAKPOINT

• At breakpoint from maximum inflation in air, the PetO2 is typically 62 ± 4 mmHg and the PetCO2 is typically 54 ± 2 mmHg, and the longer the breath-hold the more they change.

It is remarkable that adults normally cannot breath-hold consistently to unconsciousness, even under laboratory supervision. Nunn (1987) estimates that consciousness in normal adults is lost at $PO_2$ levels below $\sim27$ mmHg and $PCO_2$ levels between 90 and 120 mmHg.

BREATH HOLDING BREAKPOINT

• Breakpoint levels close to these have been reported, e.g. $PetO_2$ levels as low as 24 mmHg, $PetCO_2$ levels as high as 91 mmHg and breath-hold durations of 14 min or more (Schneider 1930, Ferris et al 1946, Klocke and Rahn 1959)

BREATH HOLDING IN PRACTISE
BREATH HOLDING IN PRACTISE

- World-renowned Brazilian track coach Luiz De Oliveira used breath hold training with Olympic athletes Joaquim Cruz and Mary Decker, who set six world records in 800-Metre to one-mile distance running events.
BREATH HOLDING IN PRACTISE

• De Oliveira, "The most important thing you can do in the race no matter how exhausted you get is to maintain your form."

• Tom Piszkin . Interview with Luiz De Oliveira. Email to: Patrick McKeown. (patrick@buteykoclinic.com) November 2012
BREATH HOLDING IN PRACTISE

• The legendary Eastern European athlete Emil Zatopek, described by the New York Times as perhaps one of the greatest distance runners ever also incorporated breath holding into his regular training.
BREATH HOLDING IN PRACTICE

• On the first day, he held his breath until he reached the fourth poplar. On the second day he held his breath until he reached the fifth poplar, increasing the distance of his breath hold by one poplar each day until he could hold his breath for the entire line of trees. On one occasion, Emil held his breath until he passed out.
1952 Helsinki Olympics brought Emil much fame and adoration after he won the 5,000 metres, the 10,000 metres and the marathon, which he decided to run on a whim, having never completed the distance before.
BREATH HOLDING IN PRACTISE

• Galen Rupp – the current American record holder of the 10,000 metres, indoor 3,000 metres, and silver medal winner at the 2012 Summer Olympics – had recently collapsed during training. Rupp’s headphones had fallen off and “he was unable to hear his coach reminding him to breathe”. 
INCREASED CREATIVITY
INCREASED CREATIVITY

• During breath holding, due to O2 consumption and a decrease in its partial pressure in the lung alveola, the flowing blood is less and less oxygenated with time. This does not mean that the brain immediately receives less oxygen.

• Journal of Human Kinetics volume 32/2012, 197-210
INCREASED CREATIVITY

• Oxygen blood saturation is admittedly lower, yet the blood circulation to the brain is higher, which is caused by the dilation of blood vessels in the brain that occurs with increased CO2 concentration.

• *Journal of Human Kinetics* volume 32/2012, 197-210
INCREASED CREATIVITY

• Yoshiro Nakamats, one of the world's most prolific inventors with over 4,000 patents.

• The floppy disk, the hard disk, and the digital watch.
INCREASED CREATIVITY

- One of his best secrets for coming up with his ideas as: "swim till almost die!"; this technique consists in swimming underwater and "holding your breath as long as possible, therefore forcing more and more oxygen into your brain so that you can think better!"