CLASS 1

OXYGEN ADVANTAGE®

BY PATRICK MCKEOWN

One Technique-Eleven Exercises

- Measurement appraisals: Body Oxygen Level Test (BOLT) & Maximum Breathlessness Test (MBT)
- Functional breathing pattern training
- Simulation of high altitude training

Functional Breathing Pattern Training

- Improve blood circulation & oxygen delivery to the cells
- Dilate the upper airways (nose) and lower airways (lungs)
- Significantly reduce exercise induced bronchoconstriction
- Improve sleep, focus, concentration and calm

Functional Breathing Pattern Training

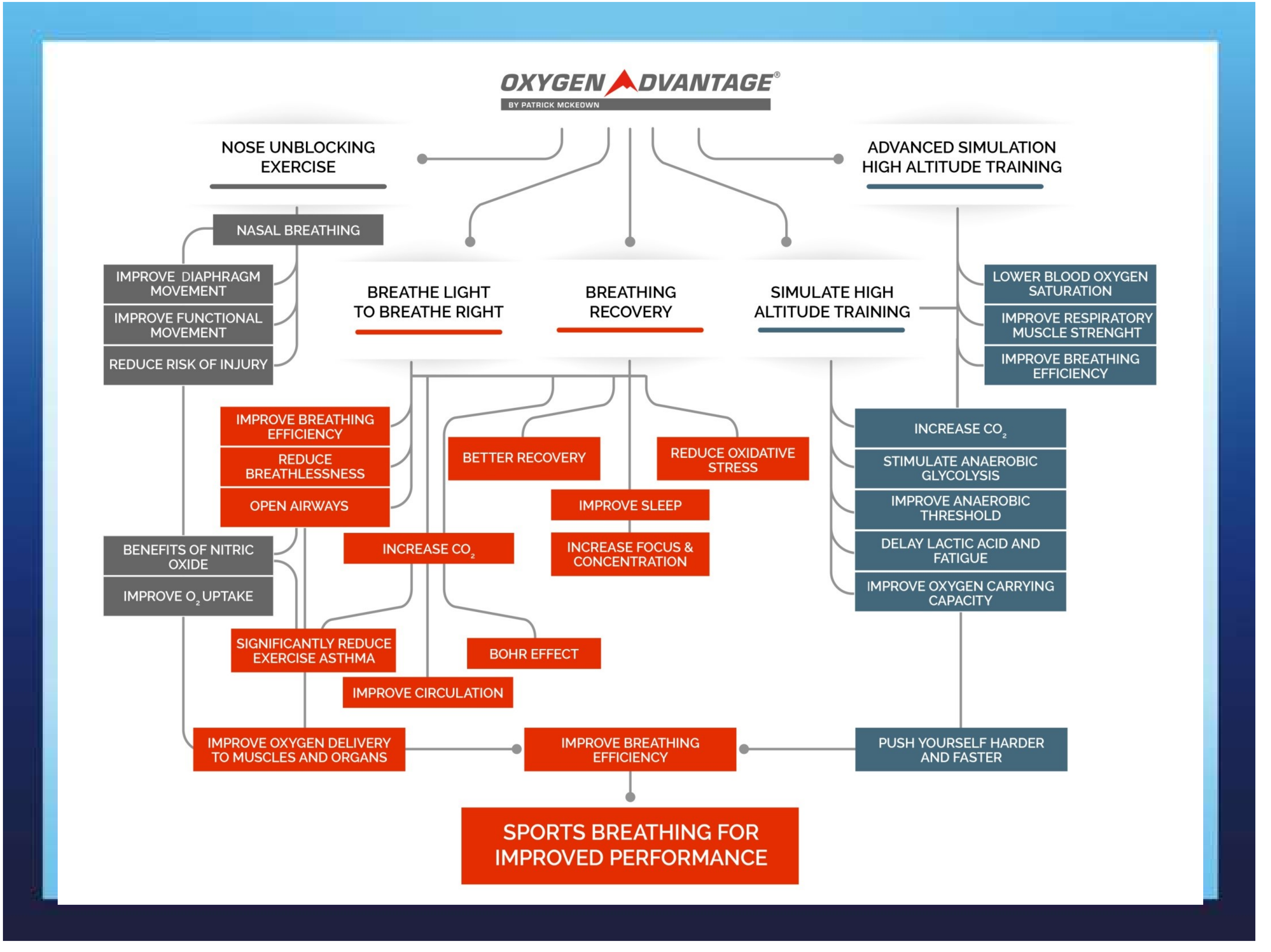
- Reduce onset and endurance of breathlessness
- Posture and spinal stabilization (poor breathing function reduces movement function)
- Reduce risk of injury
- Reduce energy cost associated with breathing
- Increase HRV, RSA and sensitivity of baroreceptors

Simulation of High Altitude Training

- Improve aerobic capacity (some non-responders)
- Improve anaerobic capacity
- Stimulate anaerobic glycolysis without risk of injury
- Increase VO_2 max and running economy
- Increase maximum tolerance to breathlessness

Simulation of High Altitude Training

- Improve respiratory muscle strength
- Improve muscle injury repair (New studies)
- Help maintain fitness during rest or injury
- Reduce free radicals and oxidative stress
- Reduce ventilatory response to hypercapnia and hypoxia


OXYGEN ADVANTAGE®
BY PATRICK MCKEOWN
NOSE UNBLOCKING EXERCISE
ADVANCED SIMULATION HIGH ALTITUDE TRAINING
NASAL BREATHING
IMPROVE DIAPHRAGM MOVEMENT
IMPROVE FUNCTIONAL MOVEMENT
REDUCE RISK OF INJURY
BREATHE LIGHT TO BREATHE RIGHT
BREATHING RECOVERY
SIMULATE HIGH ALTITUDE TRAINING
LOWER BLOOD OXYGEN SATURATION
IMPROVE RESPIRATORY MUSCLE STRENGHT
IMPROVE BREATHING EFFICIENCY
IMPROVE BREATHING EFFICIENCY
REDUCE BREATHLESSNESS
OPEN AIRWAYS
BETTER RECOVERY
REDUCE OXIDATIVE STRESS
IMPROVE SLEEP
INCREASE FOCUS & CONCENTRATION
INCREASE CO_2
STIMULATE ANAEROBIC GLYCOLYSIS
IMPROVE ANAEROBIC THRESHOLD
DELAY LACTIC ACID AND FATIGUE
IMPROVE OXYGEN CARRYING CAPACITY
BENEFITS OF NITRIC OXIDE
IMPROVE O_2 UPTAKE
INCREASE CO_2
SIGNIFICANTLY REDUCE EXERCISE ASTHMA
BOHR EFFECT
IMPROVE CIRCULATION
IMPROVE OXYGEN DELIVERY TO MUSCLES AND ORGANS
IMPROVE BREATHING EFFICIENCY
PUSH YOURSELF HARDER AND FASTER
SPORTS BREATHING FOR IMPROVED PERFORMANCE

OXYGEN ADVANTAGE®

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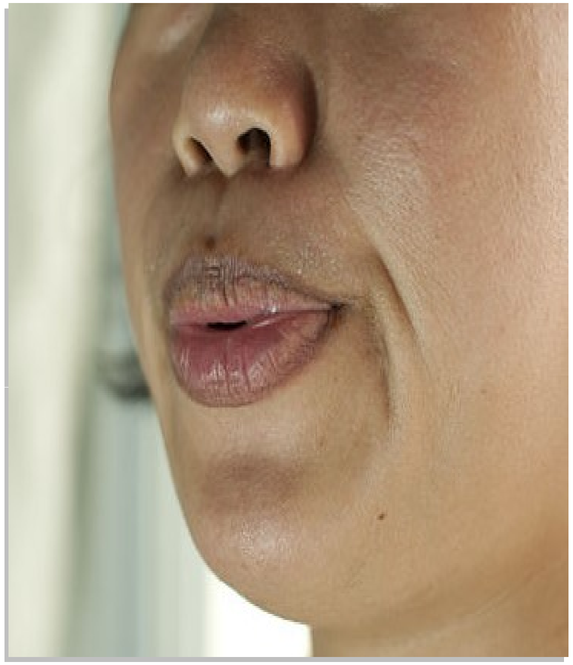
SCREENING FOR BREATHING PATTERN DISORDERS IN SPORTS

DYSFUNCTIONAL BREATHING

- Breathing through mouth
- Upper chest movement
- Hearing breathing during rest
- Frequent sighing
- Frequent yawning
- Paradoxical breathing
- Easily noticeable breathing movement during rest

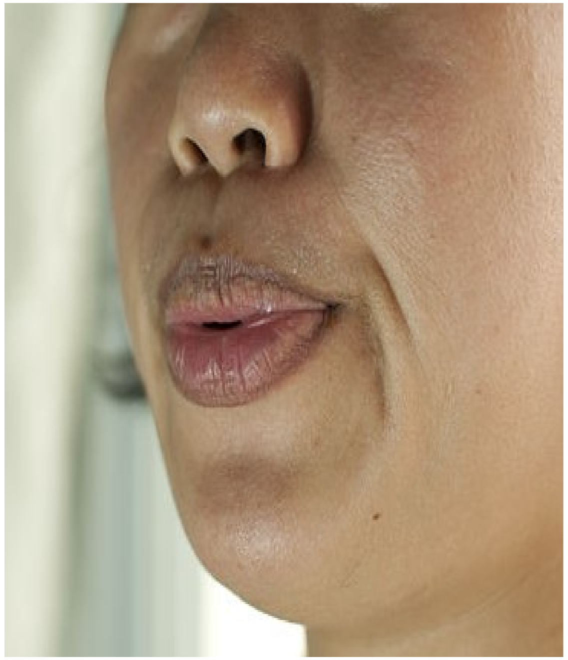


DYSFUNCTIONAL BREATHING

- Dysfunctional Breathing Patterns:

  no precise definition

Generally includes any disturbance to breathing including; hyperventilation/over breathing, unexplained breathlessness, breathing pattern disorder, irregularity of breathing.



DYSFUNCTIONAL BREATHING

- Normal minute ventilation: 4- 6 litres
- Hyperventilation- breathing in excess of metabolic requirements of the body at that time to cause hypocapnia.

STRESS

BREATHING TO EVOKE RELAXATION

- Faster
- Sigh more (irregular)
- Noticeable breathing
- Oral breathing
- Upper chest breathing

- Slow down
- Regular
- Soft breathing
- Nose breathing
- Diaphragm breathing

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

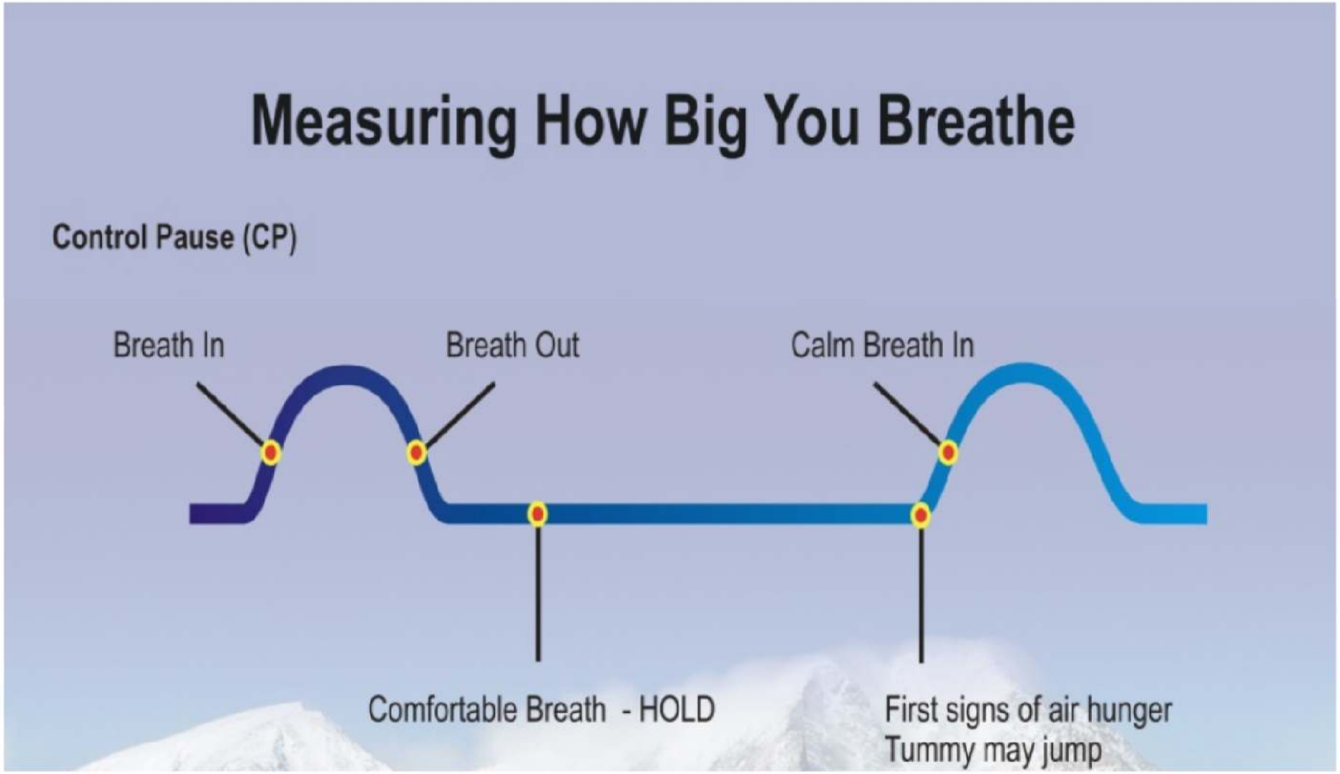
HOW SHOULD WE BREATHE?

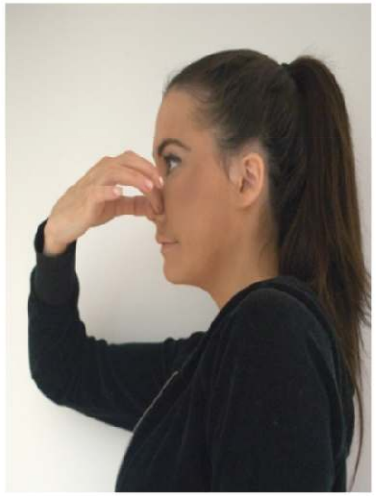
- If you took a run alongside an elite athlete in good health, would you expect her to be huffing and puffing like a train?

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





Body Oxygen Level Test (BOLT)

- 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.

- *Nishino T. Pathophysiology of dyspnea evaluated by breath-holding test: studies of furosemide treatment. Respiratory Physiology Neurobiology.2009 May 30;(167(1)):20-5*

- Voluntary breath holding duration is thought to provide an indirect index of sensitivity to CO_2 buildup.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- Dysfunctional breathing (DB) has been linked to health conditions including low back pain and neck pain and adversely effects the musculoskeletal system.

- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- Cross-country skiers of reported low back pain ever (65.4%)
- Rowers (25.6%) reported missing training because of low back pain

- Bahr R[1], Andersen SO, Løken S, Fossan B, Hansen T, Holme I. Low back pain among endurance athletes with and without specific back loading--a cross-sectional survey of cross-country skiers, rowers, orienteerers, and nonathletic controls. Spine (Phila Pa 1976). 2004 Feb 15;29(4):449-54.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- Subjects with DB have been shown to demonstrate concurrent core dysfunction.

- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- It is thought that core muscle function is altered in those with DB in a compensatory manner. The physiological drive to maintain respiration leads to core muscles functioning to assist breathing to a greater extent than during normal functional breathing.

- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- Core muscle dysfunction has been linked to many common musculoskeletal problems including LBP, ACL injury, neck pain and an overall increased injury risk.

- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- Core exercises are often prescribed as part of rehabilitation, fitness, and strength and conditioning programs with no attention paid to breathing function.

- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- No single test or screen identifies DB, which is multi-dimensional, and includes biochemical, biomechanical, and psychophysiological components.

- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- The purpose of this study was to develop a breathing screening procedure that could be utilized by fitness and healthcare providers to screen for the presence of disordered breathing.

- *The* Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- 51 subjects (27 females, 27.0 years, BMI 23.3)
- Biochemical dimension- end-tidal CO2 (ETCO2)
- Biomechanical dimension, the Hi-Lo test
- Psychophysiological dimension, the Self Evaluation of Breathing Symptoms Questionnaire (SEBQ) and Nijmegen questionnaires

- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- No strong correlations between the three measures of DB. Five subjects had normal breathing, 14 failed at least one measure, 20 failed at least two, and 12 failed all three.

- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- Easily obtained clinical measures of BHT (25 seconds) and four questions (FMS) can be utilized to screen for the presence of DB.

- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- Breath hold time (BHT) was measured by testing the functional residual capacity, which is a measure of how long a subject can hold their breath starting at the end of a normal exhale until first involuntary muscle activity was noted by the tester.

- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- Do you feel tense?
- Do you feel cold sensation in your hands or feet?
- Do you notice yourself yawning?
- Do you notice yourself breathing through your mouth at night?
- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

SCREENING TOOL FOR DYSFUNCTIONAL BREATHING

- If the screen is passed, there is an 89% chance that DB is not present. If the screen is failed, further assessment is recommended.
- Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. The International Journal of Sports Physical Therapy, Volume 12, Number 5, October 2017, Page 774.

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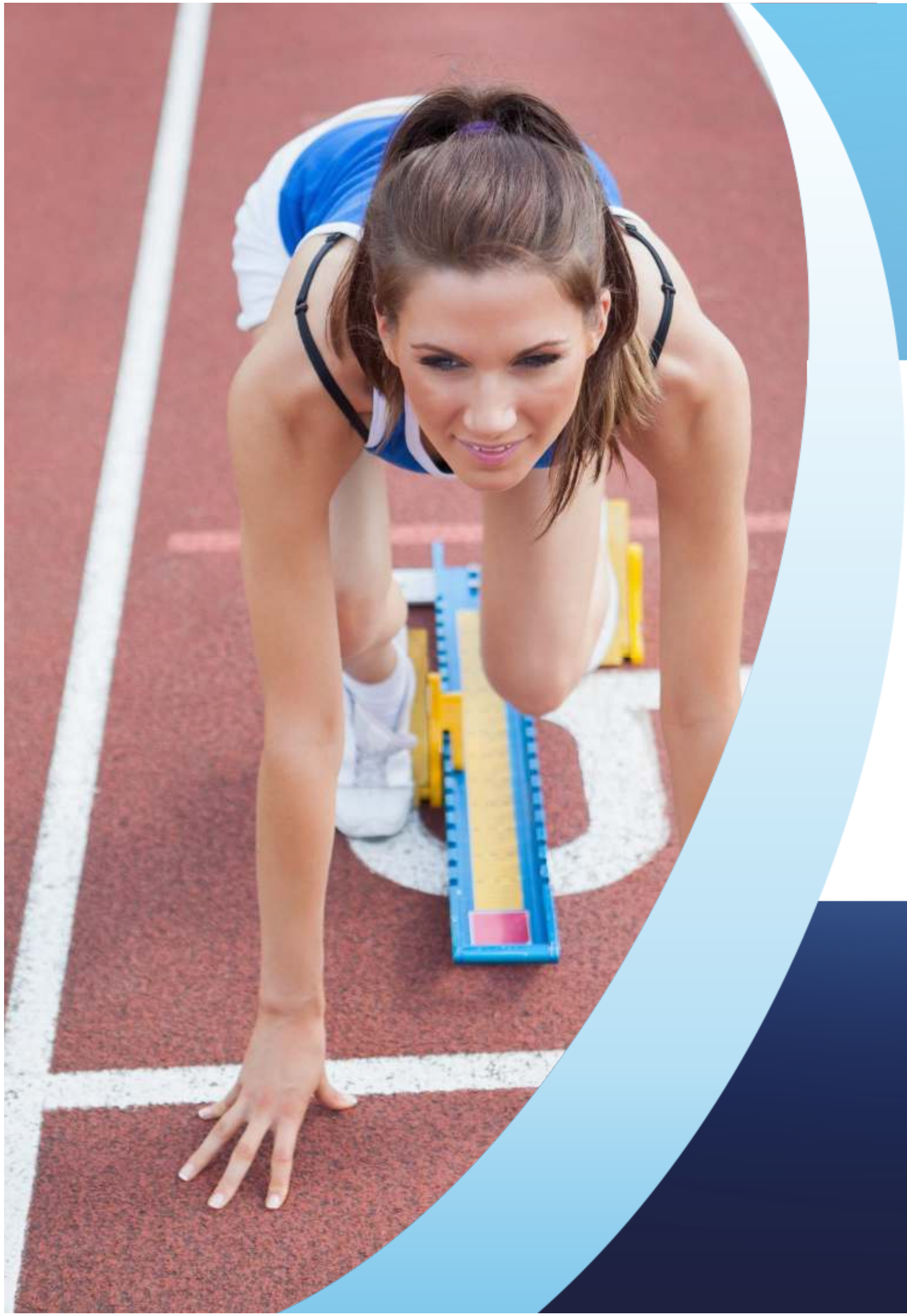

BPD IN SPORTS

BPD AND INJURY

- BPDs known as hyperventilation syndrome and rapid breathing alters the body's pH producing respiratory alkalosis; which results in an array of symptoms including headache, dizziness, chest pain, trouble sleeping, breathlessness, light sensitivities, exhaustion, and cramps.

Chapman E et al. A clinical guide to the assessment and treatment of breathing pattern disorders in the physically active: part 1. The International Journal of Sports Physical Therapy, Volume 11, Number 5, October 2016, Page 803.

BPD AND INJURY

- An athlete with an abnormal breathing pattern during physical activity may experience premature breathlessness or muscle fatigue, resulting in decreased performance.

Chapman E et al. A clinical guide to the assessment and treatment of breathing pattern disorders in the physically active: part 1. The International Journal of Sports Physical Therapy, Volume 11, Number 5, October 2016, Page 803.

BPD AND INJURY

- BPD – non reflective of cardiovascular fitness
- If breathing is off during rest, it is off during physical exercise

BPD AND INJURY

- Normal breathing mechanics play a key role in posture and spinal stabilization. Breathing Pattern Disorders (BPD) have been shown to contribute to pain and motor control deficits, which can result in dysfunctional movement patterns.

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.

BPD AND INJURY

- Correction or re-education of BPDs can result in new neural connections and restoration of normal motor control patterns in the CNS.

Chapman E et al. A clinical guide to the assessment and treatment of breathing pattern disorders in the physically active: part 1. The International Journal of Sports Physical Therapy, Volume 11, Number 5, October 2016, Page 803.

BPD AND INJURY

- “If breathing is not normalized, no other movement pattern can be.”

Chapman E et al. A clinical guide to the assessment and treatment of breathing pattern disorders in the physically active: part 1. The International Journal of Sports Physical Therapy, Volume 11, Number 5, October 2016, Page 803.

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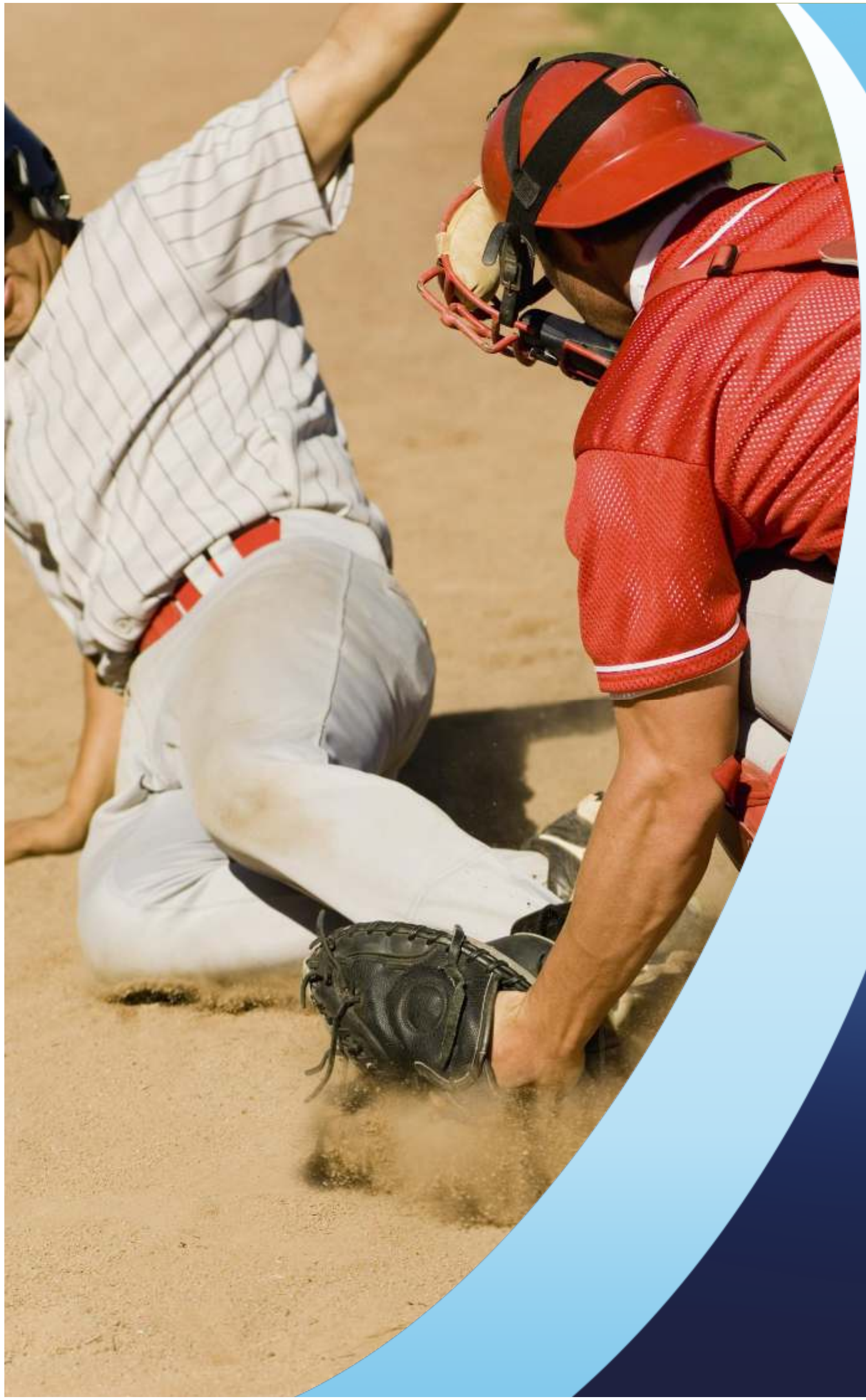


BPD ARE MULTIDIMENSIONAL

BPD AND INJURY

- Thoracic breathing can have an acute effect on respiratory chemistry, specifically a decrease in the level of carbon dioxide (CO_2) in the bloodstream. This causes the pH of the blood to increase, and a state of respiratory alkalosis results. Respiratory alkalosis can trigger changes in physiological, psychological, and neuronal states within the body that may negatively affect health, performance, and the musculoskeletal system.

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.

BPD AND INJURY

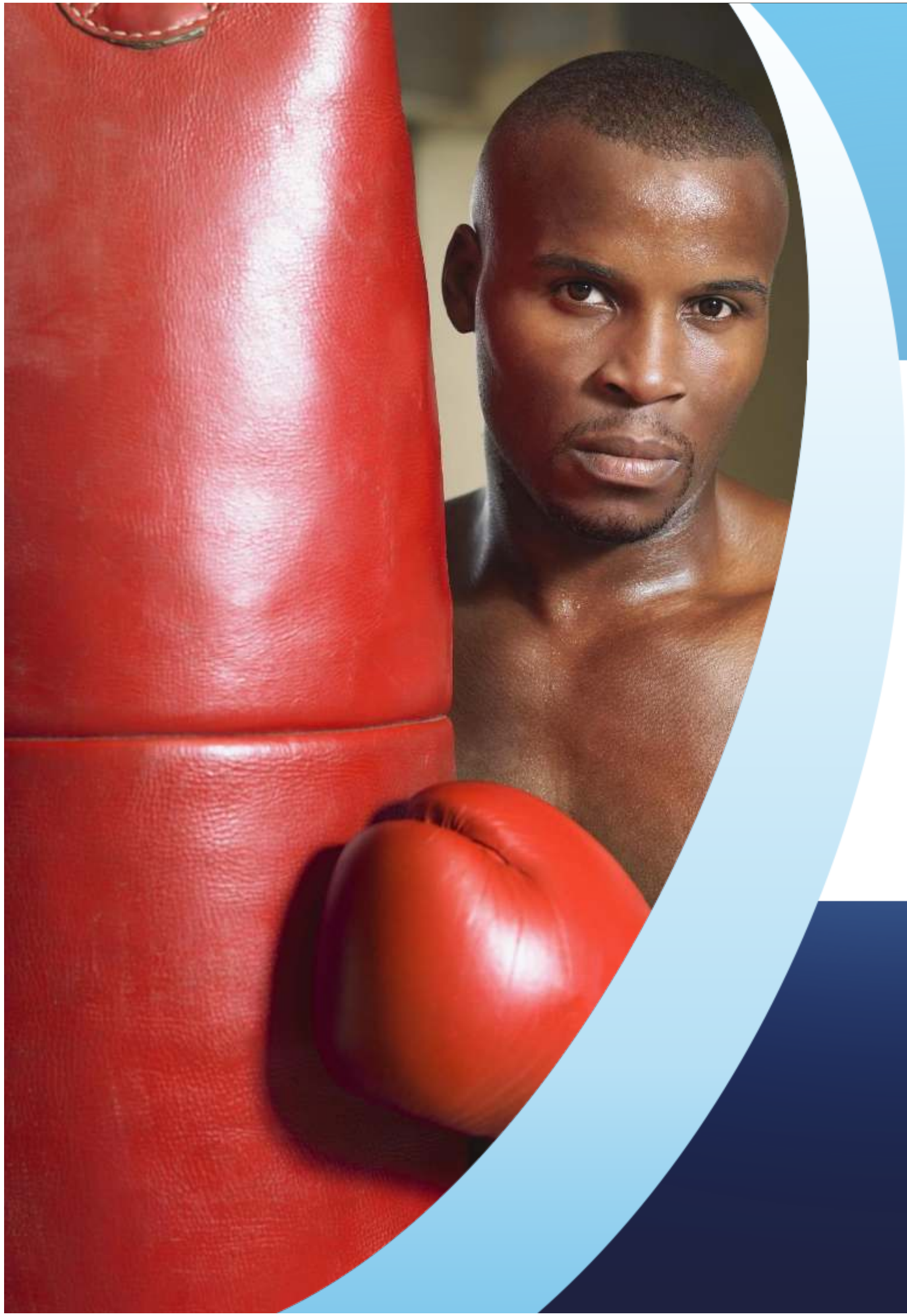
- Method to assess this biochemical aspect of respiratory function is capnography. Capnography measures average CO_2 partial pressure at the end of exhalation, known as end tidal CO_2 ($etCO_2$) and has good concurrent validity when compared to arterial CO2 measures.
- Normal ranges are between 35-40 mmHg, while values of <35mmHg were suggestive of a BPD.

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.

BPD AND INJURY

- Breath-holding ability is an aspect of breathing functionality that is commonly disturbed in individuals with dysfunctional breathing. Times of <20 seconds are proposed to indicate the presence of BPD and to correlate with resting CO2 levels.

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.



THE STUDY

BPD AND INJURY

- 34 healthy men and women
- Resting $etCO_2$ and resting RR were the most sensitive measures of BPD with over 70% of subjects having disordered results.
- Between 50 to 60% of participants had abnormal scores

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.

BPD AND INJURY

- Functional movement is defined as the ability to produce and maintain an adequate balance of mobility and stability along the kinetic chain while integrating fundamental movement patterns with accuracy and efficiency.

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.

BPD AND INJURY

Variables	Mean ± SD	MIN	MAX
FMS™ Score	14.71 ± 1.84	12.00	19.00
Rest $etCO_2$ (mmHg)	33.70 ± 2.74	27.70	39.33
Active $etCO_2$ (mmHg)	34.28 ± 2.44	29.37	40.17
Rest RR (breaths/min)	18.39 ± 3.41	12.25	25.2
Active RR (breaths/min)	24.30 ± 3.06	17.65	30.64
BHT (sec)	19.22 ± 5.05	10.57	34.13
NQ	9.24 ± 6.43	0.00	27.00

FMS™, Functional Movement Screen™ ; $etCO_2$, end-tidal carbon dioxide; RR, respiratory rate; BHT, breath-hold time; NQ, Nijmegen Questionnaire

BPD AND INJURY

- The Functional Movement Screen (FMS) has been shown to accurately predict injury in individuals who demonstrate poor movement patterns.

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.

BPD AND INJURY

- Subjects who scored higher on the Nijmegen Questionnaire, had a lower $etCO_2$ during the FMS™ test and a higher RR.

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.

Nijmegen Questionnaire

	Never – 0	Rarely - 1	Sometimes - 2	Often - 3	Very often - 4	Total
Chest pain						
Feeling tense						
Blurred vision						
Dizzy spells						
Feeling confused						
Faster/deeper breathing						
Short of breath						
Tight feelings in the chest						
Bloated feeling in the stomach						
Tingling fingers						
Unable to breathe deeply						
Stiff fingers or arms						
Tight feelings around the mouth						
Cold hands or feet						
Palpitations						
Feelings of anxiety						
TOTAL SCORE						

A score of over 23 out of 64 suggests a positive diagnosis of hyperventilation syndrome

BPD AND INJURY

- Individuals with a high RR during the FMS™ had lower $etCO_2$ measurements.

- Resting $etCO_2$ measurements were significantly different between diaphragmatic (mean=35.47 mmHg) and thoracic breathers (mean=32.14 mmHg)

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.

BPD AND INJURY

- Individuals with a less efficient breathing pattern scored worse on the FMS™ compared to those subjects who had normal breathing patterns. Resting $etCO_2$ was positively correlated with FMS™ scores.

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.

BPD AND INJURY

- The results from this study show that a relationship exists between elements of BPD and functional movement.

- Both biomechanical and biochemical measures of BPD had a significant association with FMS™ scores.

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.

BPD AND INJURY

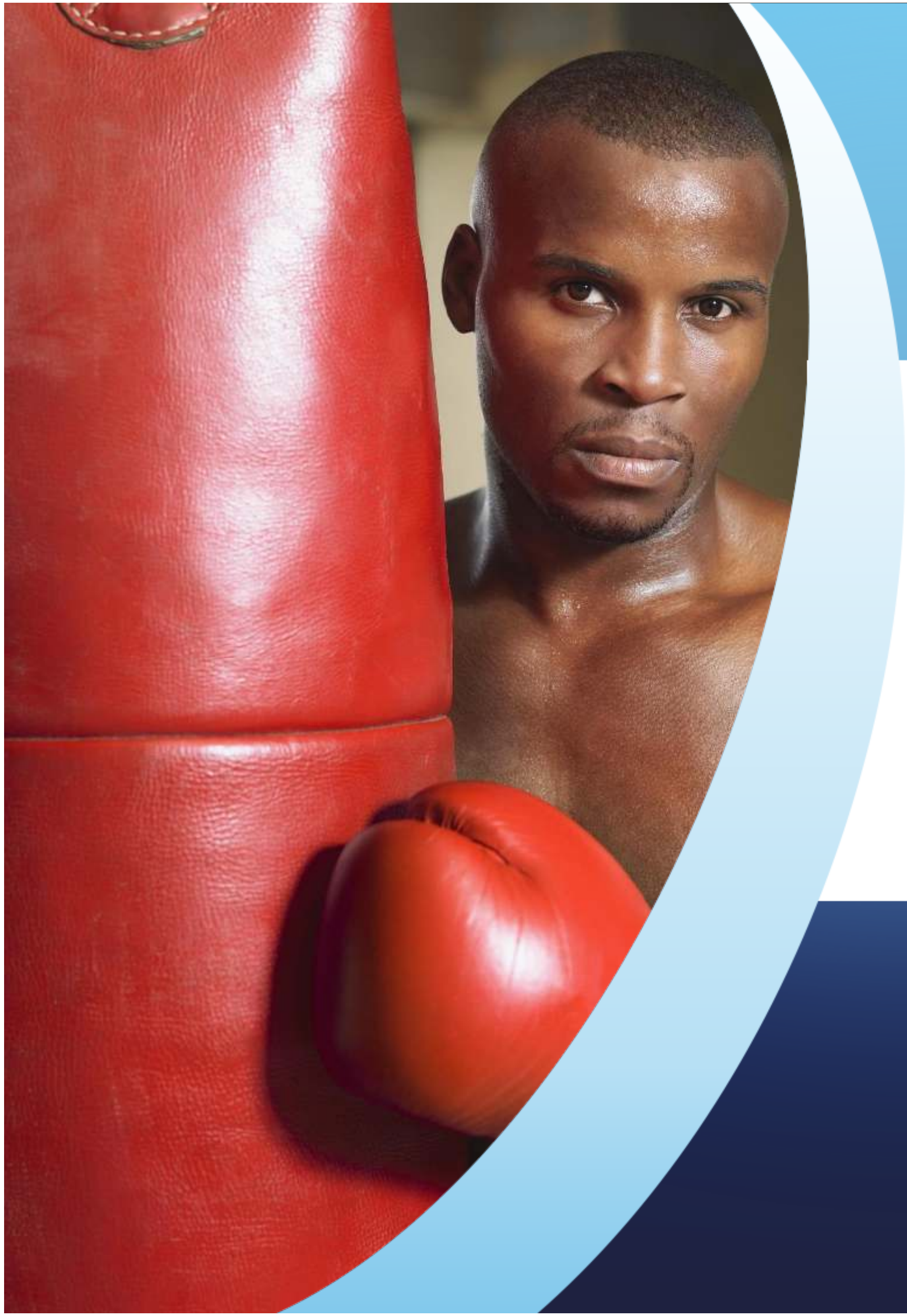
- Furthermore, 87.5% of individuals who were in the Pass group on the FMS™ were classified as diaphragmatic breathers. These results demonstrate the importance of diaphragmatic breathing on functional movement.

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.

BPD AND INJURY

- A higher $etCO_2$ level, indicating efficient respiratory function, was positively correlated with a higher FMS™ score.

Bradley H, Esformes J. Breathing pattern disorders and functional Movement. The International Journal of Sports Physical Therapy, Volume 9, Number 1, February 2014.



Maximum Breathlessness Test (MBT)

Maximum Breathlessness Test (MBT)

- Exhale normally through nose
- Walk at a normal pace while holding the breath
- Count the maximum number of paces that you can hold your breath

- Goal 80 to 100 paces
- Less than 60 paces- significant room for improvement

Maximum Breathlessness Test (MBT)

- Psychological willpower and endurance influence the duration of the breath holding.
- The breakpoint of breath holding is preceded by the onset of respiratory movements.
- These irregular contractions of the inspiratory muscles reduce the unpleasant sensation in the lower thorax and abdomen that occurs progressively through a breath-holding period.
- Discomfort signals are sent from the diaphragm to the brain- terminates the breath hold

Maximum Breathlessness Test (MBT)

- People need to gasp for air long before their brain or body runs out of oxygen (the obvious limitation).
- After decades of research, the diaphragm, which contracts to inflate the lungs, plays a key role.
- **The best hypothesis is that the diaphragm sends** signals to the brain about how long it has been contracted and how it is biochemically reacting to depleted levels of oxygen or rising levels of carbon dioxide. Initially those signals cause mere discomfort, but eventually the brain finds them intolerable and forces breathing to start again.

Parkes 2006. April 2012, ScientificAmerican.com

Maximum Breathlessness Test (MBT)

- The duration of breath-holding after deep inspiration is a function of several factors
- Chemoreception (chemosensitivity)
- Mechanoreception (light stretching receptors)
- The impact of descending cortical respiratory drive
- Cognitive component

The first two are involuntary but the most important (Ilyukhina and Zabolotskikh, 2000; Parkes,2006)

Trembach Nikita, Zabolotskikh Igor. Breath-holding test in evaluation of peripheral chemoreflexsensitivity in healthy subjects. Respiratory Physiology & Neurobiology 235 (2017) 79–82

OXYGEN ADVANTAGE®

BY PATRICK MCKEOWN

Respiratory Physiology

Definitions

- **PO_2**

- Partial pressure of oxygen in the blood.

- **SpO_2**

- Percentage of oxygenated hemoglobin versus total hemoglobin in arterial blood. (allows 70 times more O_2 to be carried)

Definitions

- Normoxia: normal levels of oxygen (SpO2 95- 99%)
- Hypoxia: deficiency in the amount of oxygen entering the tissues

  (SpO2 less than 91%)
- Hyperoxia: when cells, tissues and organs are exposed to higher than normal partial pressure of oxygen

Definitions

- Normocapnia: normal arterial CO2, about 40mmHg
- Hypocapnia: below normal arterial CO2. Less than 37mmHg
- Hypercapnia: abnormally elevated levels of CO2. Greater than 45mmHg

CARBON DIOXIDE NOT JUST A WASTE GAS!

PRIMARY STIMULUS TO BREATHE

Carbon dioxide production is about 200 ml per minute.

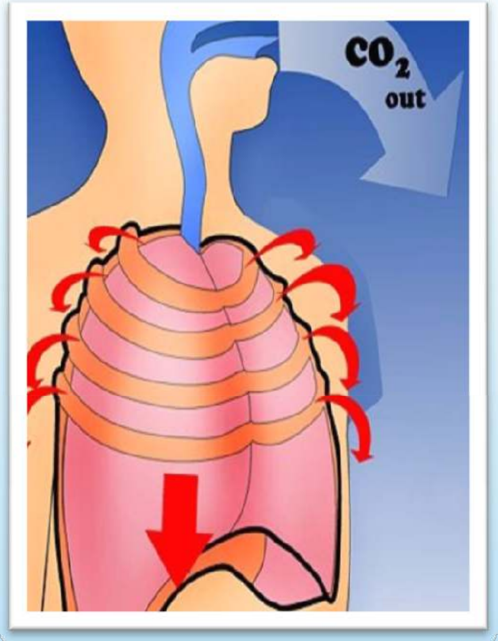
Ezeilo and Green 1979

PRIMARY STIMULUS TO BREATHE

- The regulation of breathing is determined by receptors in the brain stem which monitor the concentration of carbon dioxide (CO_2) along with the pH level and to a lesser extent oxygen in your blood.

PRIMARY STIMULUS TO BREATHE

- Among these, CO_2 provides the strongest stimulus to ventilation. For example, a slight increase (e.g., 2–5 mmHg) in arterial blood pCO_2 can more than double the ventilation



Journal of Psychosomatic Research 60 (2006) 291– 298

PRIMARY STIMULUS TO BREATHE

- 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.

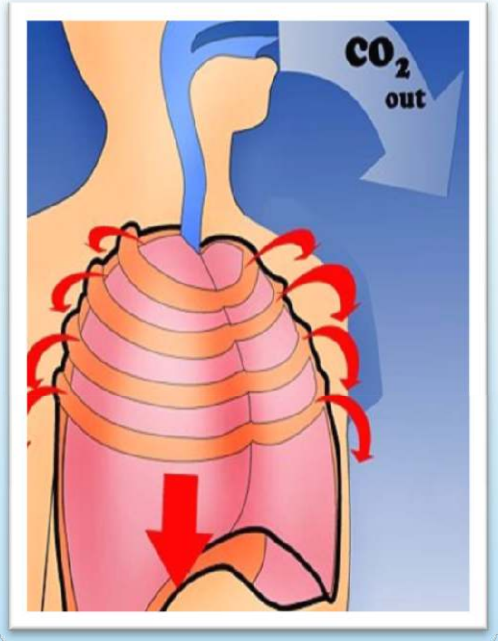
HOW SHOULD WE BREATHE?

- The threshold for the hypoxic ventilatory response is approximately 60mmHg (Loeschcke & Gertz, 1958), which is reached during exercise at an altitude of about 2500m (Ferretti et al., 1997; Cardus et al)

X. Woorons1, P. Mollard1, A. Pichon1, C. Lamberto1,2, A. Duvallet1,2, J.-P. Richalet. Moderate exercise in hypoxia induces a greater arterial desaturation in trained than untrained men. Scand J Med Sci Sports 2007: 17: 431–436

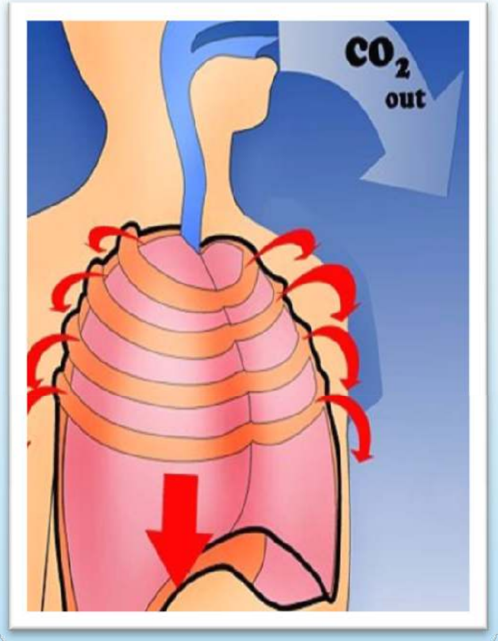
PRIMARY STIMULUS TO BREATHE

- Chemical sensors of breathing (chemoreceptors)
- Brain stem- controls regular breathing. Responsive to CO_2
- Carotid arteries- underneath the angle of the jaw. Responsive to CO_2 and low levels of O_2



PRIMARY STIMULUS TO BREATHE

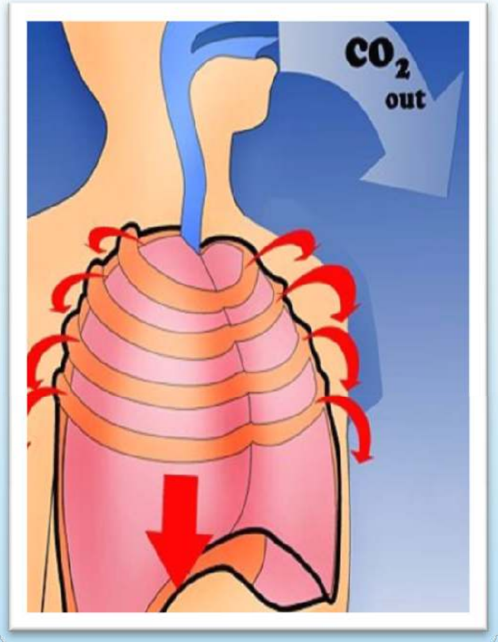
- The brain stem is the most primitive part of the brain.
- In the brain stem is the medulla containing the respiratory center with separate inspiratory and expiratory centers.



Timmons B.H., Ley R. *Behavioral and Psychological Approaches to Breathing Disorders*. 1st ed. . Springer; 1994

PRIMARY STIMULUS TO BREATHE

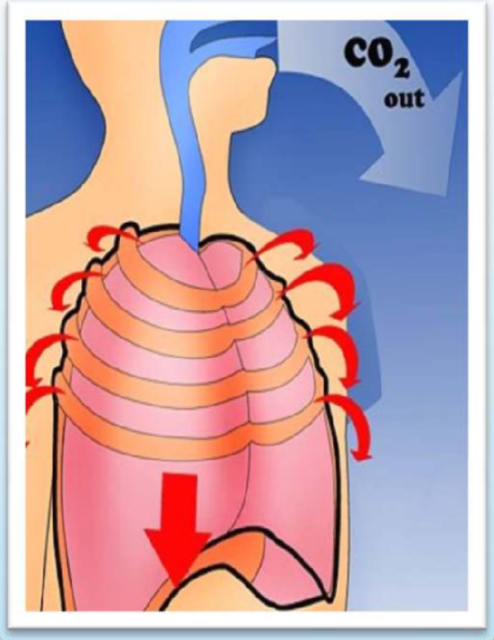
- Normal PCO_2 is 40mmHg
- An increase of PCO_2 above this level stimulates the medullary inspiratory center neurons to increase their rate of firing. This increases breathing to remove more CO_2 from the blood through the lungs.



Timmons B.H., Ley R. *Behavioral and Psychological Approaches to Breathing Disorders*. 1st ed. . Springer; 1994

PRIMARY STIMULUS TO BREATHE

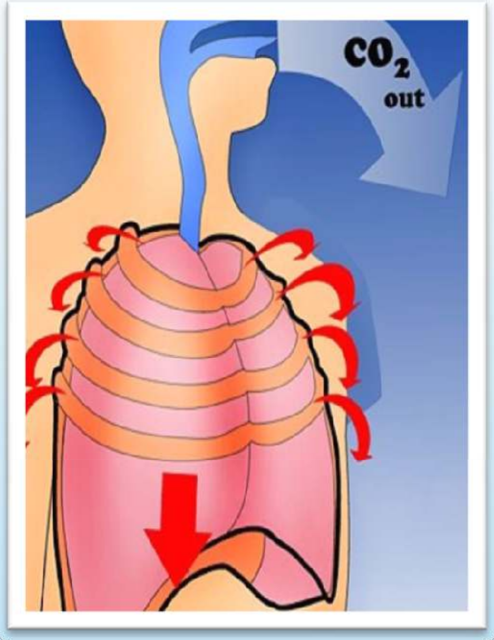
- Impulses sent down the spinal cord and through the phrenic nerve which innervates the diaphragm, intercostal nerves and external intercostal muscles- producing inspiration.
- At some point the inspiratory center decreases firing, and the expiratory center begins firing.



Timmons B.H., Ley R. *Behavioral and Psychological Approaches to Breathing Disorders*. 1st ed. . Springer; 1994

PRIMARY STIMULUS TO BREATHE

- On the other hand, a decrease in the PCO_2 below 40mmHg causes the respiratory center neurons to reduce their rate of firing, to below normal-producing a decrease in rate and depth of breathing until PCO_2 rises to normal.

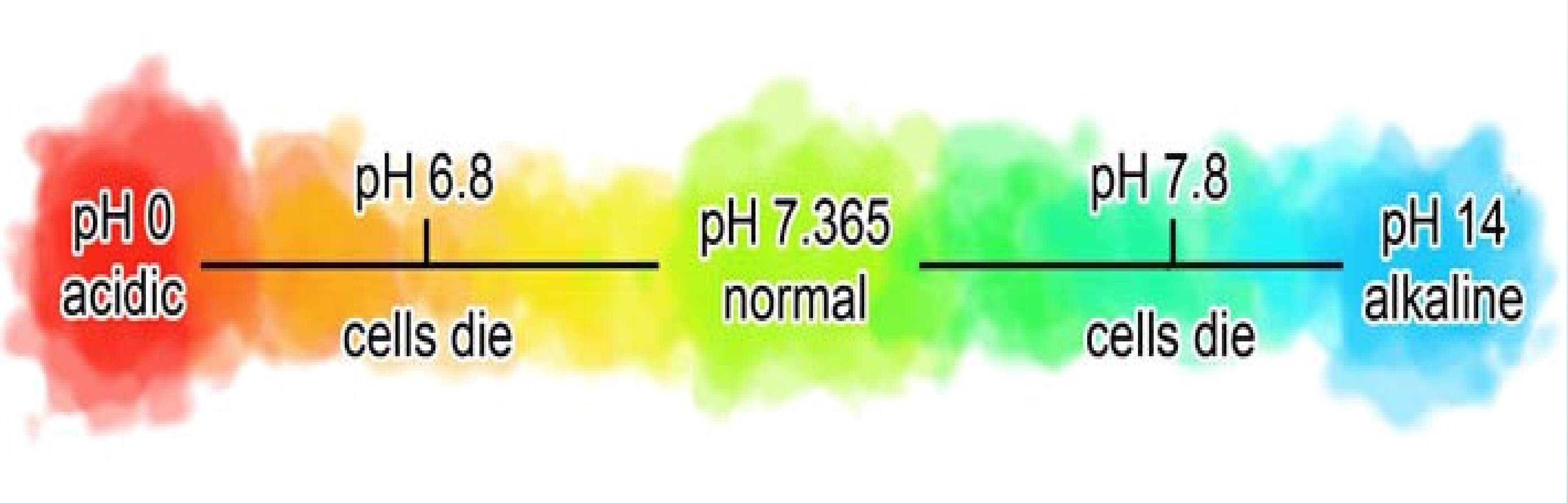


Timmons B.H., Ley R. *Behavioral and Psychological Approaches to Breathing Disorders*. 1st ed. . Springer; 1994

PRIMARY STIMULUS TO BREATH

- However, breathing more than what the body requires over a 24 hour period conditions the body to increased breathing volume.

pH CO_2 Link


pH 0
acidic
pH 6.8
cells die
pH 7.365
normal
pH 7.8
cells die
pH 14
alkaline

pH CO_2 Link

- 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

pH CO_2 Link

CO2 in blood carried three ways:

- 5% dissolved in plasma
- 30% combined with blood proteins
- 65% converted to bicarbonate ions for its transportation in the blood

- $CO_2 + H_2O = H_2CO_3 = H^+ + HCO_3^-$

- CO2 –24 times more soluble in the blood than O2. Similar amounts in lungs and blood. aCO2 depends entirely on ACO2.

pH CO_2 Link

- CO2 disassociates into H+ and HCO3- constituting a major alkaline buffer which resists changes in acidity. (reversibly bind H+)

pH CO_2 Link

- 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 sub sequentially decreases to allow accumulation of carbon dioxide and normalisation of pH.

pH CO_2 Link

- However, when over breathing continues for hours/days, bicarbonate excess is compensated by renal excretion.
- Hypocapnia and pH shift are almost immediate; adjustment of bicarbonate takes time. (Originally thought hours to days, but can occur within minutes)

Lum LC.. Hyperventilation: the tip and the iceberg. J Psychosom Res..1975 ;(19(5-6):375-83

pH CO_2 Link

- 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. Journal of the Royal Society of Medicine. 1988 Sep; 81(9): 532–536.

pH CO_2 Link

- In this equilibrium small amounts of over breathing 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. Journal of the Royal Society of Medicine. 1988 Sep; 81(9): 532–536.

pH CO_2 Link

- There is little difference between CO2 in alveoli and arterial blood. The level of arterial blood depends entirely on alveolar CO2.
- Alveolar CO2 depends on breathing volume.

Bohr Effect

- In 1904, Christian Bohr, a Danish biochemist discovered that “the lower the partial pressure of carbon dioxide (CO_2) in arterial blood ($paCO_2$), the greater the affinity of hemoglobin for the oxygen it carries”

Bohr Effect

- That is, an increase in blood CO_2 concentration, which leads to a decrease in blood pH, will result in hemoglobin proteins releasing their load of oxygen.

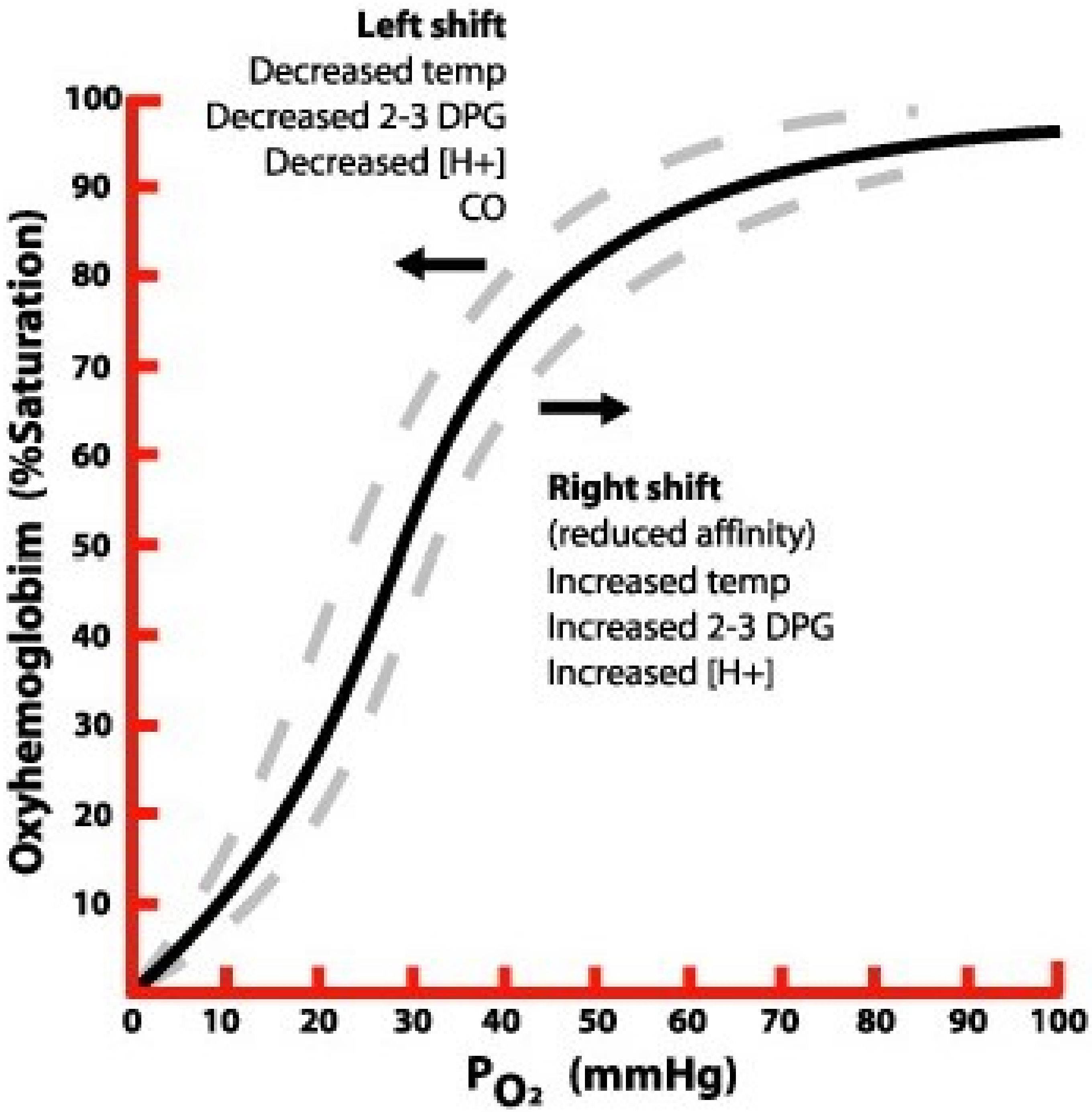
- This discovery was named **‘The Bohr Effect’.**

Bohr Effect

- In other words, the lower the partial pressure of CO_2 in arterial blood, the lower the amount of oxygen released by hemoglobin to cells for production of energy.

Bohr Effect

- By nasal breathing, aCO_2 is higher, the oxygen that is inhaled is more efficiently distributed to fatigued tissues which should in theory improve health and athletic performance and recovery, with practice of the technique.



Left shift
Decreased temp
Decreased 2-3 DPG
Decreased [H+]
CO
Right shift
(reduced affinity)
Increased temp
Increased 2-3 DPG
Increased [H+]
Oxyhemoglobim (%Saturation)
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
P_{O_2} (mmHg)

OXYHEMOGLOBIN DISSOCIATION CURVE

- **Horizontal axis; PO_2**

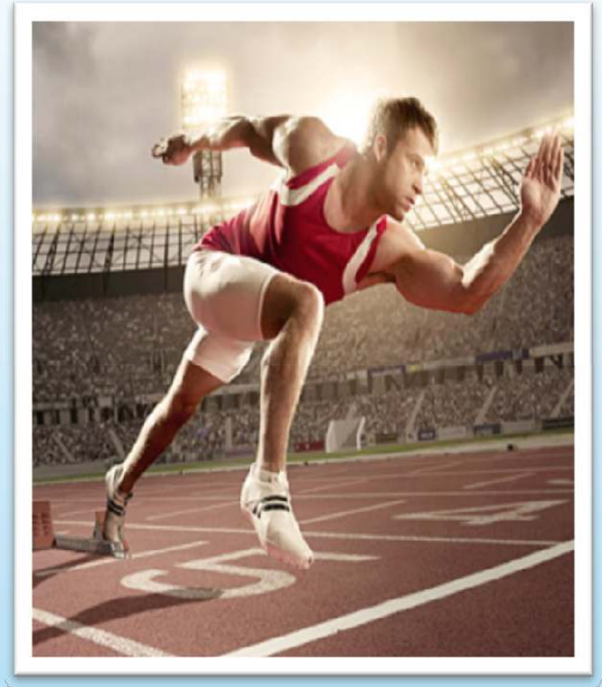
- Partial pressure of O_2.

- **Vertical axis: SpO_2**

- Percentage of oxygenated hemoglobin versus total hemoglobin in arterial blood. (allows 70 times more O_2 to be carried)

OXYHEMOGLOBIN DISSOCIATION CURVE

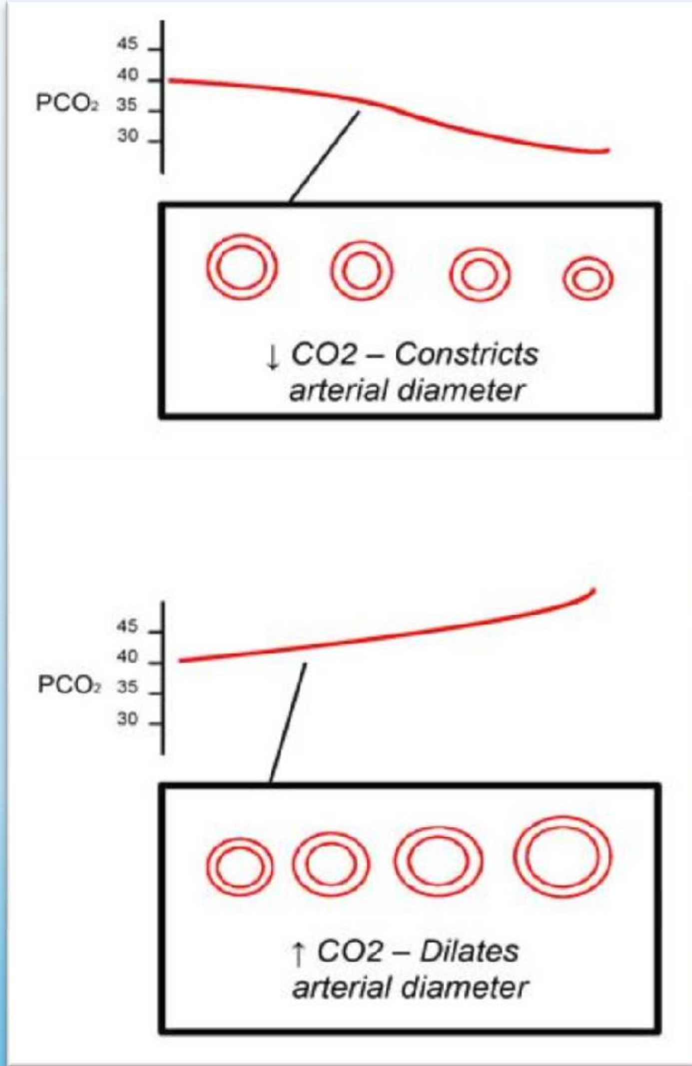
- An exercising muscle is hot and generates carbon dioxide and it benefits from increased unloading of O2 from its capillaries.



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

CONSTRICTION OF CAROTID ARTERIES

- A primary response to hyperventilation can reduce the oxygen available to the brain by one half.



Timmons B.H., Ley R. Behavioral and Psychological Approaches to Breathing Disorders. 1st ed. . Springer; 1994. page 7

CO_2 Response to Hyperventilation

Arterial carbon dioxide tension and alveolar carbon dioxide are virtually identical and arterial CO_2 is directly proportional to alveolar CO_2.

A decrease in $PaCO_2$ (arterial) can result from hyperventilation. A decrease in $PaCO_2$ without a change in the bicarbonate increases the blood pH producing respiratory alkalosis.

Lung (1983) 161 : 257-273

CO_2 Response to Hyperventilation

The changes in the arterial CO_2 content and tension are greatest during the first 30 to 60 seconds of acute hyperventilation.

$PaCO_2$ can decrease to half the normal value after less than 30 seconds of hyperventilation.

A single deep expiration and inspiration can reduce the PaC02 by 7- 16mmHg.

Lung (1983) 161 : 257-273

CO_2 Response to Hyperventilation

With a decrease in $PaCO_2$ and respiratory alkalosis, there is a vasoconstriction of the cerebral arteries and reduced cerebral blood flow. There is a decrease in oxygen delivery to the brain on the basis of both the Bohr effect and the decreased cerebral blood flow.

Lung (1983) 161 : 257-273

CO_2 Response to Hyperventilation

Diminished cerebral blood flow may be responsible for the dizziness, faintness, visual disturbances, and impaired psychomotor behaviour that are commonly described during hyperventilation.

Lung (1983) 161 : 257-273

Carbon Dioxide Anomalies

Carbon Dioxide Anomalies

Widely assumed that HVPT (voluntary overbreathing for 1-3 minutes) reproduce symptoms by inducing hypocapnia. However, in most subjects the mechanism of symptoms did not require a fall in PCO_2.

Howell. The Hyperventilation Syndrome: a syndrome under threat? Thorax. 1997 S2

Carbon Dioxide Anomalies

The act of overbreathing itself (stress stimulus) can bring on symptoms.

Howell. The Hyperventilation Syndrome: a syndrome under threat? Thorax. 1997 S2

Carbon Dioxide Anomalies

- In addition to the "metabolic" pathway via the respiratory centre, there must also be a motor "behavioural" pathway involved in the control of breathing. This pathway presumably mediates increased ventilatory drive associated with muscular exercise when the PCO2 is either unchanged or lower than at rest.

Howell. The Hyperventilation Syndrome: a syndrome under threat? Thorax. 1997 S2