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Hyperventilation

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Introduction

Shallow water blackout (syncope or fainting) is loss of consciousness caused by cerebral hypoxia towards the end of a breath-hold dive, when the swimmer does not necessarily experience an urgent need to breathe and has no other obvious medical condition that might have caused it. Shallow water blackout can easily lead to drowning.

Although the body requires oxygen (O_2) for metabolism, low O_2 level normally does not stimulate breathing. Rather, breathing is triggered by rising carbon dioxide (CO_2) level in the bloodstream. As a result, cerebral hypoxia can lead to syncope without ever experiencing air hunger. There is no bodily sensation that warns a swimmer of an impending blackout.

Hyperventilation before apnea dive escalates the risk of shallow water blackout. It artificially depletes CO_2, causing a low blood carbon dioxide condition called hypocapnia. Hypocapnia reduces the reflexive respiratory drive, allows the delay of breathing and leaves the swimmer susceptible to loss of consciousness from hypoxia.

Chemistry

pH (power of Hydrogen) is the measurement of the acidity or basicity of an aqueous solution. Pure water (H_2O) is neutral, with a pH close to 7.0 at 25°C. Solutions with a pH lower than 7 are acidic and solutions with a pH greater than 7 are basic or alkaline.

However, water that has been exposed to air is mildly acidic. This is because carbon dioxide (CO_2) dissolves in water to form carbonic acid (H_2CO_3), which dissociates into bicarbonate (HCO_3^-) and hydrogen ions (H^+).

$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$

Carbon dioxide + water $\rightleftharpoons$ carbonic acid $\rightleftharpoons$ bicarbonate + hydrogen ions

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Biology / Physiology

The pH of blood is regulated to stay within the narrow range of 7.35 to 7.45. The most common disorder in acid-base homeostasis is acidosis, which means an acid overload in the body, generally defined by pH falling below 7.35. Alkalosis refers to a condition in which there is reduced hydrogen ion concentration of arterial blood plasma (alkalemia), generally when pH of the blood exceeds 7.45. This acid-base balance is finely tuned by a number of homeostatic mechanisms, including the bicarbonate buffering system.

A person's breathing rate influences the level of CO_2 in his blood. Breathing that is too slow or shallow causes respiratory acidosis; while breathing that is too rapid leads to hyperventilation, which can cause respiratory alkalosis.

CO_2 is one of the mediators of local autoregulation of blood supply. If its level is high, the cerebral vessels dilate (vasodilatation) to allow a greater blood flow. Conversely, low concentration of CO_2 in the blood (hypocapnia) raises the blood's pH value; this alkalinisation of the blood causes vessels to constrict (vasoconstriction).

This shift in the CO_2 chemistry associated with hyperventilation causes physiological changes such as hypoxia, cerebral constriction, coronary constriction, blood and cellular alkalosis, cerebral glucose deficit, ischemia, buffer depletion, bronchial constriction, calcium imbalance, magnesium deficiency, muscle spasms, and fatigue.

Hyperventilation

Hyperventilation can be brought about voluntarily, by taking many deep breaths in rapid succession.

Hyperventilation can also occur involuntarily:

- When someone exercises over his VO_2 max, unable to transform oxygen into energy beyond a certain level but hyperventilate in an effort to do so.
- Also, while experiencing excitement or anxiety, the body releases the hormone epinephrine (adrenaline) leading to responses including hyperventilation.

Conclusion

Safety practices like the following should be observed:

- Before dive:
  - Do not perform hyperventilation voluntarily.
  - Take a moment to relax and allow blood oxygen and carbon dioxide to reach equilibrium.

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  - Breathe absolutely normally; allow the body to dictate the rate of breathing to make sure the carbon dioxide level is properly calibrated.
  - If excited or anxious about the dive, take extra care to remain calm and breathe naturally.

- During dive:
  - When the urge to breathe comes on near the end of the dive, immediately seek access to air.
  - Never dive alone. Dive in buddy pairs; when one is diving, the other is to supervise at all time.

- Buddy pairs must both be proficient in rescue and cardiopulmonary resuscitation (CPR).

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