What is the role of nutrition in the acid base balance and is it possible to manipulate the balance to enhance freediving performance?

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2008-12-10

The history of acid base balance

The acid base balance is a popular topic in the alternative medicine. The usual explanation is that you can avoid a lot of different diseases if you ingest foods with a more alkaline load compared to foods with a high acidic load. The spokesmen claim that we ingest too much of the foods contributing to an acidic load and that it results in a more acidic blood which generate a long list of diseases. However there is no evidence that this is the case. The background to these theories goes a long way back in time. As early as (1577–1644), Jan Baptista van Helmont visualised acids as sharp rodlets dissolving substances that resisted all other liquids and alkalis as rings blocking the sharpness of rodlets[1]. Diseases were assumed to be the result of an abnormal fermentation leading to the development of an acid or alkaline excess in body fluids. In order to maintain a balance, a surplus of acids should be treated with alkali and vice versa. This highly speculative holistic concept of life as an equilibrium of acids and alkalis had a profound influence on European history of the mind. Later, Henry Bence Jones (1813–1878) observed in detail the variations in the acidity of urine in relation to food consumption. He speculated that conversion of oxygen leads to the formation of an acid in the body and therefore recommended alkaline waters. Howard Hay (1866–1940) advocated a diet with an excess of alkali and a separate intake of carbohydrates and proteins. Around 750 000 copies of the nutritional advice by Hay have been sold in Germany, Switzerland and Austria in the last 40 years[1]. However, at this time the scientists had not the knowledge of the mechanisms behind the acid base homeostasis in the blood. The body are in fact very good at maintaining the acid base homeostasis when healthy.

pH in the blood

Normal pH in the blood optimizes the enzyme action and a healthy metabolism and therefore, the body always tries to maintain the pH within a narrow range. Prolonged abnormal pH leads to disordered metabolism and illness. Intracellular homeostatic mechanisms help maintain arterial blood pH close to 7.4. It is impossible to sustain life with an arterial pH below 6.8 or above 7.8[2]. There are several buffering systems in the blood which attenuate changes in the concentration of hydrogen ions e.g. hemoglobine, phosphate, plasma proteins and salts. The intracellular pH is lower (6.8) than in the arterial serum and the intracellular enzymes works optimal at a pH between 6.7-6.9[3].

Regulation of the arterial pH

Organic acid anions of alkali salts are compounds that influence the acidity. There are considerably different rates of the absorption in the intestine between different nutrients relevant to the contribution of acid or alkali load. For instance, if $MgCl_2$ is ingested where the uptake of Mg^{2+} is about one third and the uptake of Cl^- is ~ 95%, would lead to an excess of Cl^- entering the blood. This has to be compensated due to the principle of electroneutrality. So what to do? The solution is to compensate with Na_2CO_3 secreted from the pancreas where the Na^+ enters the blood to compensate for the excess of Cl^- and the CO_3^{2-} compensate for Mg^{2+} in the lumen of the intestine, forming a carbonate salt[4]. In this particular case, this leads to a depletion of carbonate, means a loss of buffering capacity. In other words, this is an example of an acid load. One example of alkali production is during the ingestion of sodium citrate which yields carbonate and Na^+ when metabolized which increase the alkali reserve or blood base pool[4].

When consuming protein which contain sulphur rich amino acids (methinonine, cysteine), the formation of sulphuric acid is promoted which lowers the pH. At the same time, increased intake of protein significantly improves the capacity for renal net acid excretion by stimulating urinary ammonium excretion. Ammonia is a hydrogen ion acceptor and forms ammonium with the hydrogen ion: $NH_3 + H^+ \rightarrow NH_4^+ \rightarrow \uparrow pH$. The kidneys initiate a complex set of responses that include increased ammoniagenesis and gluconeogenesis, enhanced acid and ammonium ion excretion, and a net production and release of bicarbonate ions. All of these changes are mediated by a pronounced increase in renal extraction and catabolism of plasma glutamine[5]. The transport of glutamine are mediated through the SN1 transporter which is Na^+ dependent and coupled with H^+ efflux[6, 7]. Apart from these mechanisms there are several other transporters and genes involved [5].

Every freediver are also aware of the compensatory processes regulated by the lungs, adjusting the pH up or down depending on the rate of ventilation (respiratory compensation). Respiratory compensation is the first mechanism used to defend the body against a low pH and the increase in ventilation is sustained until the pH reach approximately 7.3 which is 0.1 below optimal pH (7.4).

High ventilation rate:

$$H^+ + HCO_3^- \rightarrow H_2CO_3 \rightarrow H_2O + CO_2 \quad \uparrow pH$$

Low ventilation rate:

$$H^+ + HCO_3^- \leftarrow H_2CO_3 \leftarrow H_2O + CO_2 \quad \downarrow pH$$

In comparison with the respiratory compensation, the renal compensation is delayed from hours to days later.

How to manipulate the buffering capacity?

When an individual has a certain eating pattern, the system is effectively synchronized to the metabolic influence of that eating pattern. However, if you suddenly change your eating pattern towards foods with a higher acidic load, there is a lag time due to the time it takes to synthesize specific transporters in the kidney etc. This results in a slightly more acidic blood. Initially, this is compensated through an elevated ventilation rate until the proteins needed to restore the homeostasis are produced. What this means is that there is no reason to eat foods which contributes to an acidic/alkaline load with the intention to walk around with a more acidic/alkaline blood. However, if you want to slightly manipulate your buffering capacity at a narrower time range (before or in an early stage of gene activation) there are several possibilities. For instance, one can ingest sodium bicarbonate (Na_2CO_2) which is used by some athletes to increase the buffering capacity toward the formation of lactic acid. For the freediver, it might be contra productive since we want the blood to be acidic at the end of a dive to promote the release of oxygen to the tissues. Highly hypothetically, it might be more suitable for the freediver to ingest food with a higher acidic load in front of a performance since you might allow you self to ventilate to a slightly higher extent and gain oxygen in your lungs and blood with a slightly lower increase of the pH in the blood than if you ingest food with an alkaline load. This strategy would require a diet with alkaline load in between the diving periods with the change to a diet with an acidic load the last meal/meals before the dive. If this theory works in reality, the dives will not be pleasant but may contribute to a delayed blackout and probably allow ventilation to a slightly higher extent prior to the dive in comparison with an alkaline diet in front of a dive (this is far from proven and only my own reflections on what may work). The increased ventilation due to the compensation still lowers the CO_2 levels which apart from increasing the pH (which is the intention of the compensation), in it self influence the dissociation curve negatively. (Increased PCO_2 contribute to the binding of CO_2 to the N-terminus of the four polypeptide chains of hemoglobine and promote the dissociation of O_2). This “abnormal” reduction of CO_2 when compensating for the low pH induced by this diet regimen may well lead to an abolished gain in the freediving performance.

Tables regarding foods contributing to acidic vs. alkaline load are available on several different web pages. It is important to understand that “acidic” foods, like for instance citrus fruits doesn’t mean that they contribute to an acidic load since these parameters are not related.

References

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