"You Leave Me Breathless"

By
Edward H. Nessel, R.Ph, MS, MPH, PharmD.

Overview

Aside from the 1950's old rock-'n-roll tune by Jerry Lee Lewis, these words should be very familiar and ring true to every swimmer who honestly trains to go faster…

Rapid vigorous movement whether sudden or prepared is expected to bring about the body's compensating mechanisms which include the most visible and obvious: ***increased depth and rapidity of breathing.*** There have been many scientific experiments whereby normal athletes at sea-level were given pure oxygen to inhale before and after intense exercise in assumption of either delaying oxygen debt or enhancing recovery. Neither the arterial blood content of oxygen was increased nor the recovery time diminished. Since this proves that the body can not store or accumulate oxygen to any great extent, the superficial interpretation of this intense breathing response would be that it is simply the body's way of bringing back its supply of usable oxygen. But this is only partially correct.

I submit that rather than simply developing an oxygen debt or deficit as a consequence of intense body movement, the ***build up of carbon dioxide (CO2) from increased metabolism is the main cause of the sometimes nearly paralyzing symptoms of breathlessness.***

Even a benign situation like being tired (or bored) can cause the body to work at compensation by causing a ***yawning sequence***. This happens more to cause the ***blow off*** (forced exhalation) of increased ***CO2 rather than to inhale more oxygen.***

One gets drowsy in a car (and begins to yawn) with several people as passengers and closed windows and vents more so because of the build up of ***CO2*** in the air than any measured decrease in oxygen content. And this manifestation would be even more apparent and occur more quickly in aerobically conditioned athletes because of their ability to extract more oxygen from the ambient air per unit time and leave more ***CO2 to build up***.

There are three instances that come to mind, one relatively benign, and the other two intensely desperate, where exposure to cold and its ability to cause the body to produce increased amounts of CO2 have produced reactionary physiological responses. I have noticed on many occasions that simple ***exposure to prolonged cold*** would bring on the ***yawning reflex***; here, due to the ***increased metabolism*** (shivering, etc) ***necessary to raise body temperature***, ***more CO2 was produced which then needed to be blown off forcefully. The first of the other two much more intense situations was superbly depicted in the movie, Apollo 13, where, on the way back to Earth in a severely damaged space craft from the aborted moon mission, the three astronauts, exposed to a much colder ambiance than planned began to have their capsule fill up with CO2, negatively affecting their ability to function; the extractors to prevent the CO2 from building up were not operating up to specs because of battery failure. This was of grave concern for the technicians at Houston Control Center. Showing a continuingly amazing ability to engineer the astronauts out of imminent harm's way, the CO2-extractors were made operable long enough to reduce CO2 content which allowed the crew to land safely in the South Pacific. The second intense instance comes about in one of the most inhospitable immediate environments I can imagine, we see many more victims dying of CO2 asphyxiation than trauma when buried***

under snow as in an avalanche. CO2 build-up about the face with increased shivering in the enclosed near interment of snow and ice presents the fact that if the victim is not extracted within 15 to 20 minutes, the odds of finding him alive are greatly diminished.

This article will hopefully relate in part what happens to the body when it is asked to endure the vigorous activity of swimming fast. Depending upon the duration, intensity, and specific type of movement through water, and, of course, the physical condition and athletic aptitude of the participant, ***breathlessness*** is the endpoint for which to train.

This is not an easy thing to ask of an athlete, especially on a constant basis. It is one thing to become short of breath during vigorous *land-based* exercise…the body usually responds in its natural way of rapid respiration, in-and-out, without much thought given to controlling this process in any way other than the desire to recover as quickly as possible. But do the same in water, and we see a whole other story. No matter how athletic the participant, ***if one can not control the breathing part of swimming for as long as the race lasts, the whole technical aspect of the stroke usually breaks down,*** and movement through water becomes, at first, less efficient, then downright counter-productive. AND, this negativity is magnified even more with the fact that as one moves faster through the water, the liquid medium holds the swimmer back with resistance that is either squared (under the surface) or cubed (at the surface). A land-based athlete with any logic might eventually analyze this and say: "why bother?" An experienced swimmer, on the other hand, comes to realize that in the final analysis, it is ***breath control that dictates speed throughout the race.*** Mis-pace the race by taking it out too fast, or make the mistake of holding the breath too much in the beginning, and all too often the back end of the swim becomes more of a struggle than the swimmer bargained for…all because of the ***sensation*** that oxygen is in very short supply.

There are many complicated physiological processes that occur in cascade fashion when body movement becomes more demanding than staying in one's "comfort zone." There are dictums and theories about ***oxygen deficit*** versus ***oxygen debt;*** about ***recovery oxygen uptake*** or ***excess post-exercise oxygen consumption (EPOC).*** I will discuss what I feel is the prime motivator to breathe, why we do this, and what happens if we don't.

Some Physiology of the Respiratory Response to Exercise

Metabolically, to move fast in any fashion (for more than just a few seconds) creates biochemical demands that must be "caught up to" and dealt with by the body. The forced deep exhalations automatically proceeding right after vigorous movement is one way the body tries to bring back its overall pre-activity condition ***(homeostasis). Carbon Dioxide (C02) is one of the end products of metabolism; it can not be prevented from forming, but it can be prevented or at least delayed from building up.*** If there is muscular movement, ***C02*** is produced. If ***C02*** is produced in low enough amounts (light to moderate movement) it can be easily carried away by circulating blood through the muscles; there will be no buildup and no ***sensation*** to want to breathe vigorously. The typical breathing mechanism will allow for this transported ***C02*** to be adequately blown off at the lungs. The better the condition of the athlete, the more readily this process takes place.

Eventually, the more ***C02*** produced, however, the greater the responding respiration becomes. Any time ***C02 production rises to a greater extent than can be handled by the rate and depth of breathing, blood will leave the lungs with some residual CO2 in it to be re-circulated through the heart and then on to the arterial blood supply and to the body's various tissues and organ systems.*** If there is more ***C02*** in place in the circulating blood, there has to be less room for ***oxygen (02)*** to be circulated. One of the typical end-result physical markers I look for in this case is seeing ***a face with blue lips (cyanosis)*** at the completion of an anaerobic (lack of oxygen) hard swim.

Since ***C02*** is being produced throughout the body with vigorous activity, adding more to the immediate tissue environment from the circulating blood only deepens its negative effects. One such effect is actually a ***rescue mechanism*** of sorts: there are ***C02-sensors in the arterial blood supply*** which, when stimulated, produce the ***sensation of "air hunger." THIS, I feel, is the primary stimulus that causes the breathing center of the brain to want to engage in forced respiration, not what might be construed as a relative lack of oxygen.***

With rapid inhalation and exhalation of ambient air, the oxygen exchange is really not that dramatic. As an example of quick inhalation-exhalation oxygen exchange, I submit the scenario of giving CPR to one who needs resuscitation. The ambient air contains 21% oxygen on average; forced air from a rescuer into the victim only contains about 16% oxygen; this shows that the body removes only about 5% of oxygen from quickly-inspired air. In addition, even with well-trained athletes, it takes time for all the respiratory trained mechanisms to kick in…sometimes as much as three (3) minutes, so maximum oxygen consumption and oxygen exchange doesn't really come into play as quickly as the build-up of ***CO2.***

Physiologic Effects From Exposure to Altered Oxygen Ambient Air

To put this presentation in proper perspective, I must mention the importance of the amount of ***available oxygen in the ambient air*** where and when vigorous movement is initiated. Right from the start, the amount of oxygen in the air and its corresponding pressures do have an effect on athletic performance. Though this discussion is about work at sea-level, I want to show the powerful influence of available oxygen at different altitudes…

If one trains at ***sea-level*** where the relative oxygen content of the ambient air is 21%, and the barometric pressure is 760 mmHg (mercury), and the atmospheric oxygen pressure is 160mm Hg, the alveolar (air sacks in the lungs) oxygen pressure averages about 110 mmHg, and the ***arterial blood oxygen pressure rises to 96 mmHg.*** The body gets used to this constant oxygen supply at this pressure while the adaptive enzymes become "trained" to extract what oxygen they have to work with from moment to moment.

Take the altitude up to ***3000 feet*** and we see the barometric pressure drop to 687 mmHg, the atmospheric oxygen pressure drop to 142 mmHg, the alveolar oxygen pressure drop to 94 mmHg and finally the arterial blood oxygen pressure drop to 83 mm Hg***…an almost 14% drop in blood oxygen content from sea-level.***

Go to a ***mile high*** and the parameters drop to 631 mmHg barometric pressure, 132 mmHg atmospheric oxygen pressure, 85 mmHg alveolar oxygen pressure, and 75 mm Hg arterial blood oxygen pressure***…a 22% drop in blood oxygen content from sea-level***

Go to ***8000 feet*** high and the important parameters read thus: alveolar oxygen pressure drops to 69 mmHg and the arterial blood oxygen pressure falls to 63 mmHg…***an almost 35% drop in blood content of oxygen from sea-level to 8000 feet.***

These physiologic numbers (lung and blood oxygen contents) are reduced by 10-15 mmHg in normal older athletes.

(No rocket scientist needed to see that if a poorly adapted athlete pushes hard at altitude, the reduced oxygen supply will manifest the sensation of breathlessness sooner and with more intensity; any ***CO2*** buildup will happen sooner into the exercise bout and will produce a prolonged effect of breathing distress. What usually presents is what is called "dragon-breathing." This is a type of involuntary adaptive reflex whereby the distressed athlete gasps for air with facial grimaces and neck muscle contractions.)

You can see from the above listings that absolute available oxygen is extremely important to the body's ability to extract it for metabolic use; have it (oxygen) compromised in content, and the ability to utilize it is diminished immediately. Here the breathing mechanism and corresponding oxygen metabolism are stressed such that not only is the probability of CO2-build up a certainty but any help from available oxygen to try and offset this will be hard to obtain. A physical manifestation that sometimes presents when respiration is compromised and the athlete is in distress is called "dragon-breathing." Mostly seen with asthmatics but not restricted to same, "dragon-breathing" immediately signifies intensely-labored respiration. Once started the body only attends to recovery from this state at the expense of all other movement.

Holding one's breath during training provides, in my opinion, only one benefit to the swimmer. It helps somewhat in the tolerance of CO2 build-up…something that could prove decisive with streamlining off the walls and into finishes. This having been stated, I am otherwise against breath-holding while swim racing most distances.

Breathing Patterns While Swim Racing

There are ***two types of distress that the body must be trained to withstand: physiological and psychological*** Correct physiologic adaptations are hoped for with appropriate training sets throughout the main racing season. But it is the ***PERCEIVED bodily response and adaptation to the swim training that will prove to be most important in producing fast swims. How you practice is how you race!***

Cecil Colwin wrote an informative article on several aspects of breathing when swimming the four racing strokes (American Swimming, 20003, issue 5). I agree with his presentation that the ***inhalation aspect of the breathing cycle is noticeably shorter than the exhalation aspect. But I disagree with Mr. Colwin that the "used air" should not be forced out with any great effort otherwise breathlessness will ensue more quickly.*** Of course the breathing and movement through each stroke cycle should by rhythmic, but this comes with practice and experience. Learning to pace an event and control the breathing cycle is just as important as knowing how to swim the required stroke…maybe even more so. Many a good swimmer has taken a race out too hard and wished he hadn't; some are able to "feel" the mistake quickly and rely on their reserve of aerobic and anaerobic conditioning to hopefully salvage the effort, but most usually do irreparable damage physiologically (breathing-wise) and suffer the consequences.

I've seen this all too often with enthusiastic and energetic age-groupers. They get caught up in the immediate moment of competition and forget the whole concept of ***breath control for the whole race.*** The 100 yard/meter freestyle is a strong example.

Usually thought of as short enough to allow breath-holding as in the 50 free, what proves out is the fact that ***doubling the distance*** (50 to100) ***in water at full blast requires almost four (4) times the energy (actual and perceived) since stressful metabolic alterations are occurring in an accelerated rate so the back half of the race is happening in an already "unfriendly" physiologic environment.***

I suggest that the only breath-holding event be the 50 freestyle, and even here, some exhalations of ***CO2*** need to occur to assure a breath-holding strong finish. The 100 free should have the swimmer breathe every cycle going into the last 25 yards/meters where and when the athlete's ability to breath-hold during building discomfort will allow the quickest, strongest finish possible. Needless to say, this type of breath control needs to be practiced over and over for all freestyle events over a 50 so it becomes automatic during the "combat of racing."

I am against "double breathing" in backstroke only because of the negative influence on the smoothness of the stoke cycle; some gravitate to this breathing cycle because the head is out of the water and no co-ordination of head movement with breathing is absolutely necessary. But the stroke should be trained with the same breath control as freestyle: of inhalation on one arm, exhalation on the other arm.

The correct breaststroke rhythm dictates one breath per cycle, and it is here that the inhalation is much shorter than the exhalation if one is to maximize the efficiency of the underwater glide…good chance to blow out mounting ***CO2.***

The butterfly, consuming the most energy per unit time of swimming, requires regular inhalation/exhalation. World records have now been swum with breathing every cycle… just as much for controlling the breath and keeping the sense of breathlessness at bay longer into the race as for maintaining the rhythm of the stroke.

Everyone slows down towards the end of a hard race. But with proper breath control, I prefer to have my swimmers slow down *less* than their competition. Hopefully this will mean a fast swim. ***Breath control…***it keeps you in it to win it.