Pulse Oximetry and Breathing Training

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Small pulse oximeters have become widely available and can be useful for noninvasive monitoring of blood oxygen saturation by nonmedical personnel. When training control of breathing, an oximeter helps to reassure clients who hyperventilate that their oxygenation is adequate, offsetting their perception that they are not getting enough air. Low saturation may indicate a medical condition that impairs oxygen absorption. In that case, hyperventilation is a biological compensation that should not be tampered with.

A pulse oximeter measures the level of oxygen in the bloodstream. This sounds invasive, but by simply taping or pressing a photoplethysmograph sensor against a finger or earlobe, one can monitor the ongoing percentage of dissolved oxygen in the bloodstream, closely approximating what an arterial puncture would provide. “For no extra charge,” one gets the pulse rate as well. The application of such a device in doing biofeedback may not be obvious, but if one works with breathing, oximetry provides very useful information. The only way oxygen can get into the blood is through the lungs, so aberrations in breathing will affect the blood’s percentage of oxygen: Technically this is called “O₂ saturation,” or “O₂ sat.”

Oxygen saturation is measured in percentiles. Approximately 97% of the total amount of hemoglobin in the blood is filled with oxygen molecules. The range of normal is about 95%–98%. Any level below 90% is a threat to health and life.

This article will provide an understanding of the relationship between breathing volume (how much air enters and leaves the lungs per unit time) and blood oxygen saturation. A review of the fundamentals of breathing and oxygen saturation should enable practitioners to explain to clients some important facts about breathing. Using an oximeter, the practitioner’s explanation can be backed up by visible second-by-second data. The oximeter need not be attached to a computerized biofeedback system or displayed on a video monitor. The entire system can fit on the finger (the client’s, not the professional’s) and can be purchased for less than $100.00 (US).

In a breath training context, an oximeter can serve two purposes: as an educational device and occasionally as a safety measure. Clients learning to control their breathing, especially if susceptible to panic attacks, may report at times some common symptoms of hyperventilation, such as light-headedness, tingling lips and fingers, visual disturbances, and difficulty getting a deep breath. They will often conclude that “I’m not getting enough air.” Naturally they will respond to this perception with anxiety, usually making an effort to breathe more deeply and quickly. Speeding and deepening respiration can make the situation worse, but if the therapist’s advice to reduce breathing speed or volume contradicts what the client is thinking, there will be poor compliance.

A portable fingertip capnometer can turn this impasse into a teachable moment. First, an explanation of the oximeter is offered: “This device can show how much oxygen is being carried in your blood. 95%–98% is ideal. If you are truly not getting enough air, it would mean that you’re short on oxygen and this number will be low. Let’s see what your oxygen saturation level is right now.” The device is then attached to a finger or earlobe, and 30 seconds later, the oximeter provides objective information to further the discussion. Depending on the oximeter reading, there are three possibilities at this point.

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1This article is adapted from Gilbert (2011), an article in California Biofeedback, with permission.
Scenario no. 1: The saturation level is within normal limits, usually 95%–98%. This is reassuring to the client, especially if the professional has informed him or her beforehand what is normal. In this case breathing training can proceed with more confidence on both sides because the practitioner has offered evidence refuting the idea of not getting enough air.

Scenario no. 2: The saturation level is 99% or 100%. This would seem to be even better, as it indicates that the bloodstream is carrying all the oxygen it can hold. But it’s not necessarily better because it means there’s a bit more oxygen in the bloodstream and a bit less in the tissues, which is the only place where it can do any good.

Consider this analogy: A truck is delivering groceries to a grocery store, and people in the store are waiting to buy those groceries. But the truck doors are only partly open, allowing only a few groceries to be unloaded and placed on the shelves. There are plenty of groceries in the truck, but not enough groceries in the store. That’s what happens with extra-high O2 saturation. The oxygen cannot perform its function in the bloodstream; it has to be released to the tissues. The difference between 98% and 100% saturation can be significant, simulating temporary anemia, and the higher number is more likely during a state of hyperventilation.

Hyperventilation lowers CO2 because more is being exhaled than is being replaced by the body. As a result, hemoglobin molecules are stimulated to retain oxygen instead of releasing it. The opposite occurs when CO2 is above normal: Hemoglobin releases more of its oxygen so that it can diffuse into the tissues and provide essential fuel (This is called the Bohr effect; McArdle, Katch, and Katch, 2005, p. 309). Therefore, holding one’s breath will raise CO2 and speed the release of oxygen, which works out well when no new oxygen is coming into the lungs. Holding one’s breath will naturally make oxygen saturation go down; having emphysema, chronic obstructive pulmonary disease (COPD), or some condition that simulates holding one’s breath will do the same.

Scenario no. 3: The O2 saturation is low, perhaps below 85%. Holding one’s breath for 3 minutes would cause this; oxygen in the bloodstream gets depleted and is not being replenished. High altitude can cause this kind of oximeter reading. Emphysema can also, as can a failing heart. Anything associated with poor absorption in the lungs, poor access to fresh air at reasonable pressure, or inadequate circulation will lower O2 saturation. A low reading like this will not be caused by hyperventilation alone.

This third scenario involves the “safety measure” part mentioned previously. Low O2 saturation means the body is in trouble and is trying to obtain enough oxygen to keep the brain and body going. In this case, hyperventilation may be happening for good reason. Do not offer a paper bag for breathing into; this would further restrict the oxygen available and could lead to serious hypoxia. This is also not the best time to educate someone about the value of abdominal breathing, slower breathing, or prolonged exhalation. The low levels could indicate a serious problem. If the person has emphysema, is chronically short of breath, and knows it, then one might advise slow steady abdominal breathing—especially with some extra pressure in the lungs produced by pursed-lips breathing. But most likely such individuals with chronic emphysema already know what to do.

If one uses a capnometer to monitor exhaled (“end-tidal”) CO2, this combination provides even more power, and some capnometers even have oximeters built in, allowing continuous measurement of end-tidal CO2 and oxygen saturation simultaneously. With a capnometer the hyperventilation-related drop in CO2 can be measured instead of hypothesized, creating considerably more credibility for the client, whose brain may already be muddled from the cerebral hypoxia. Besides discouraging oxygen release from the bloodstream, low CO2 raises pH levels and stimulates vasoconstriction of smooth muscle. Cerebral, nervous, and cardiac tissue are all susceptible to this hypoxic effect (for more details, see Gilbert, 1998, 2005).

Now imagine that a practitioner has both instruments: If the client is moderately hyperventilating, with a low CO2 (32 mmHg, say) and a high O2 saturation (such as 100%), he or she might ask, “Is that why I sometimes get tingly and light-headed, like I am right now?” The simple answer is yes, but one could expand with “Nothing good comes of breathing too much. You’re exhaling more CO2 than your body is producing, and the imbalance causes many weird symptoms. Your brain feels the effects of low oxygen, while the oximeter shows plenty of oxygen in your bloodstream. If you want oxygen to be distributed to your brain and other important organs, you need to breathe less.”

At that point, the client usually gets interested and discovers that breathing slightly less (more slowly and/or less deeply) raises the CO2 reading to normal and causes the oximeter reading to drop from 100% into the 95%–98% range. As a bonus, the hands and feet may become warmer, because of the relaxation of peripheral blood vessels. Also, thinking usually becomes clearer and anxiety diminishes. This is a good time to demonstrate the effects of holding
Figure 1. Illustration of the effect of normal breathing disrupted in opposite directions: approximately 2 minutes of hyperventilation (A) and holding one’s breath (B) followed by resuming normal breathing pattern. Reducing CO₂ through overbreathing raises O₂ saturation (A), which decreases release of O₂ to the tissues; raising CO₂ by holding one’s breath lowers O₂ saturation (B), which increases release of O₂ into the tissues. The drop to zero in the bottom CO₂ trace is an artifact of exhalation being interrupted, so no end-tidal values are available.
one’s breath briefly, so that the client can observe the drop in $O_2$ and the rise in the $CO_2$ reading (see Figure 1).

Hyperventilation, if transient, is usually harmless, though it has some effects on cortical and cardiac circulation and on autonomic tone. Chronic hyperventilation, however, will create a sustained chemical imbalance, a physiological adaptation to the altered breathing in which the kidneys retain more acid to compensate for acid loss through overbreathing. The primary stimulus to breathe at any given moment comes not from a low oxygen level, but from a rise in carbon dioxide in the blood, which is normally associated with inadequate exhalation or oxygen-poor air. When a capnometer shows $CO_2$ consistently lower than 35 mmHg (a prime definition of hyperventilation), it may indicate a false “set point,” which encourages the excess breathing to continue. This adaptation lowers the threshold for breathing drive, or “air hunger,” so that a person feels an urge to breathe more and sooner than usual. So the abnormal begins to feel normal, and a vicious circle is established. The physiological priority is to maintain proper pH, and the body will tolerate other deficits to do this.

This compromise compensation, largely by the kidneys adjusting pH, can be reversed if the chronic-hyperventilation client practices getting by with a little less air, in essence, going on an “air diet.” Learning to tolerate and resist the urge toward excessive breathing will in time renormalize the body chemistry, so that the restored breathing style starts to feel more comfortable. This can happen within weeks, but the client first has to see a reason to work at it. An oximeter offers the reinforcement by providing some objective evidence of success. The devices are pocketable and inexpensive enough to loan out, unlike capnometers.

Pulse oximeters have proven their value in emergency environments such as ambulances, serving as a check against the assumption that deep, rapid breathing is nothing but anxiety. A popular remedy for an episode of hyperventilation is breathing into a paper bag (rebreathing exhaled air), which does increase $CO_2$ in the blood, but it also restricts access to fresh air, and this can be dangerous. Before oximeters were routine, ambulance attendants sometimes made the mistake of offering the paper bag solution to someone with a heart problem, emphysema, asthma, or some other disorder that limits oxygen delivery. Deaths have been reported from this kind of mistake (Callaham, 1989).

Athletes use oximeters to monitor their oxygen saturation during intense exercise so they can adjust their breathing for optimal oxygen delivery. Airline and private pilots use pulse oximeters for safety checks on themselves because low oxygen saturation, a risk at high altitudes, indicates cerebral hypoxia, which prevents the brain from working correctly—not so good when flying an airplane.

Oximeters can be useful in behavioral rehabilitation as well. For instance, Giardino, Chan, and Borson (2004) conducted a study of patients with COPD and examined whether training and practice of breathing would improve exercise tolerance. Study participants first learned to breathe more slowly and deeply in a way that increased heart rate variability. Then they began practicing using their skills while testing how far they could walk in 6 minutes—a standard measure of exercise tolerance for patients with heart and lung disease. They used portable finger-mounted oximeters to judge their oxygen saturation. Sensations of leg muscle fatigue and shortness of breath provided natural biofeedback, but the oximeters were more precise: 90% saturation or above meant they were encouraged to keep walking, and below that number meant they could take a rest and practice restorative breathing. This biofeedback-in-action protocol proved effective, with most participants more than doubling their distance walked. The results also included clinically significant improvements in quality of life.

In conclusion, pulse oximeters are available at a cost ranging from about $39 up to several thousand dollars, the higher prices representing extra features needed in hospitals. Some have wireless transmitting via Bluetooth and memory storage. See Schnapp and Cohen (1990) for more details on oximetry, including possible artifacts that lead to false readings. Any clinician in the position of advising people to breathe differently can feel a bit safer with an oximeter available, and it will provide an added bonus of demonstrating to the client the real value of breathing within the body’s normal limits.

References


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