Re: Mt.Wilson

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- *From*: Mike Simmons <mikes@xxxxxxxxxxxxxxxxxxx>
- *Date*: Wed, 14 Dec 2005 17:42:42 −0800

On Wed, 14 Dec 2005 10:11:36 −0800 (PST), Brian Tung wrote:

> Mike Simmons wrote:
>> A lot less oxygen. The decrease in atmospheric pressure is approximately
>> exponential so the higher you go the more of a difference each incremental
>> increase makes. Think of going from sea level to 4000 feet. Most people
>> won't notice any change. 4000 to 8000 is noticeable but not huge. 8000 to
>> 12,000 matters a lot and acclimatization really matters (which certainly
>> isn't true for going from sea level to 4000 feet).
>
> Not quite. I mean, I think your subjective characterization feels
> right, but the physics isn't. The atmospheric pressure does scale
> roughly exponentially, but it's a negative exponential, with a scale
> height of about 8 km. In other words, atmospheric pressure (in atm) is
> approximately exp(−h/8 km).

Hi Brian,

Other than not saying that it's negative −− which I think is obvious in the context −− what isn't right about what I said regarding the physics? (BTW, scale height for Earth is about 7.4km.)

> I think the reason we don't notice a whole lot from 0 feet to 4,000 feet
> unless we exert ourselves is that we normally have a surplus of oxygen
> in the air we breathe; otherwise, we wouldn't be *able* to exert any
> effort. At some point in increasing altitude, though, the surplus runs
> out and we feel the effects, something that NBA players who visit the
> Denver Nuggets can attest to.

Rather than physics, you're referring to physiology and what you say isn't right. We don't have a "surplus of oxygen" to use. There is a physiologic equivalent to what you say, though, which is the sigmoid shape of the oxygen disocciation curve −− (the relation between partial pressure of oxygen [pO2] in inspired air and the percentage of hemoglobin that is saturated with oxygen (i.e., oxyhemoglobin) [sO2]. The curve is at a plateau for normal people at sea level and for some drop in pO2 but once you reach the steep part of the curve a small change in pO2 makes a big difference in sO2 (this point is called desaturation). It's the amount of oxyhemoglobin in the arterial blood that matters, and it's not a linear relation (as, e.g., for dissolution) because of the affinity of hemoglobin for molecular oxygen.

But this isn't that big a factor in normal people because respiratory drive isn't affected much by a decrease in blood oxygen anyway. This is contrary to common belief and doesn't seem to make sense at first so it's normal to assume hypoxia drives respiration. But the partial pressure of dissolved carbon dioxide (CO2) in the arterial blood is the primary factor that drives respiration. This makes sense since as you exercise you produce more CO2 but because of the above sigmoid nature of the oxygen disocciation curve your available oxygen in arterial blood doesn't change. If you were to breath air with a little CO2 in it you'd find yourself breathing very hard to try to reduce your arterial pCO2 even though your pO2 was normal. Reduce the O2, though, and there's a far smaller drive to breath harder, which is eventually overcome by the decrease in CO2 that works the opposite.

When you go to altitude the amount of oxygen in the blood drops once the partial pressure of oxygen in the air drops enough to get to the steep part of the oxygen disocciation curve (which gives an effect like what you said above) but the carbon dioxide doesn't change. Thus mountaineers have to learn to breath harder even at rest because the oxygen drive is so weak. Thus you end up with too little CO2 in the blood which itself can be a problem but it's better than being woozy all the time. You can't overdo it even to try and get more O2 because the CO2 level will overcome it (and there are strong effects of too little CO2 that are detrimental anyway, like constricting arterial blood flow to the brain). Purse−lipped breathing −− puckering your lips on exhalation to maintain a higher pressure in the mouth and thus in the lungs −− is one way that lung patients and mountaineers can increase oxygen in the blood. It makes it look to the lungs like you're at lower altitude.

If you're still unconvinced of the difference in the hypoxic and hypercapnic drives then let me know and I'll arrange for you to breath a mixture of 21% O2 with 5% CO2. That's convince you *real* fast. ;−)

Your assumption that we have a surplus of oxygen that allows us to exercise is not right. You're ignoring the physiologic effect of exercise on breathing and blood flow. The oxygen available to the blood is thus increased many−fold. The pressure is almost the same (the pressure in the alveoli drops as you use more oxygen) but blood flow is greatly increased, which brings blood in contact with the alveoli faster so it can pick up oxygen quicker and thus carry more to the muscles. Try keeping your breathing the same while increasing your exercise and you'll see it doesn't work. Actually, what you'll notice there is the hypercapnic drive −− the increase in CO2 that causes you to breath harder −− not a decrease in oxygen.

> It doesn't take much to acclimate if you're just sitting around. Cabins
> on airplanes are routinely pressurized only to 0.74 atm, the equivalent
> of an altitude of 8,000 feet.

That's not acclimatization. That's just not using much oxygen or producing more than normal CO2. There is a long list of physiologic response to chronic exposure to altitude that take place, chief among them (in this discussion) a shift of the oxygen disocciation curve so that a lower pO2 in the lungs (i.e., in the atmospher) produces a higher sO2 in blood than it would at sea level, as though the hemoglobin's affinity to oxygen increases. There also changes in response to the decreased CO2 in the blood, which is a problem because it raises the blood's pH (acidity), which is kept in very strict balance on a short−term basis by adjusting breathing to increase or decrease blood CO2 (the kidneys do this by adjusting the metabolic rather than respiratory pH). If you fly to 8000 feet and you're comfortable sitting around you'll feel differently if you start to exercise heavily. After acclimatizing for a few days you can not only rest comfortably but exercise as well.

>> This is what makes it so amazing that people can go to great heights. The
>> higher you go the greater the effect of going even higher. How some
>> climbers can do what they do is beyond me.
>
> Again assuming a scale height of 8 km, the atmospheric pressure at the
> top of Mt Everest is only about 0.33 atm!

The pCO2 of arterial blood in Everest summiters not using supplemental oxygen has been measured at 7 mmHg. Normal is 40 mmHg. A change of 2 mmHg is enough to make you start breathing harder. A change of 5 mmHg will cause you to pant. They're breathing so hard to get the oxygen they need −− partly due to training (you learn to breath more when you feel woozy) and partly because the hypoxic drive definitely has an effect at that kind of unreal altitude −− that they've put themselves in a state that would be fatal to the average person. You know how you get dizzy when you hyperventilate at rest? That's due to a drop in CO2 in the blood of a few mmHg, which causes constriction of the peripheral arteries including the carotid to the brain. I can't figure out how they stay concsious, let alone alive. I'm not sure if that's been explained yet. My theory is that they aren't human −− nothing else fits the observed data.

Mike Simmons
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