On Teaching Exercise Physiology: Energy for Escape and the Wiener Dog Brigade

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Adenosine tri-phosphate (ATP) is the chemical compound of life. A heart fails to beat; a thought is not processed; a cell fails if the body's production of this compound ceases. It is the compound that enables biologic work to occur. It is the back-drop of many lectures involving exercise physiology and human metabolism I teach. At times, my lectures pertain to how energy is used to facilitate performance of physical work. But, the simple fact is, energy is necessary for survival. To that end, I often employ survival in my lectures so my students can appreciate the limitations of pathways used to produce ATP in a more concrete way while also gaining a sense of why these pathways have developed. Of course, when talking about survival, it doesn't hurt to twist in a smidgen of humor here and there. My hope is that the importance of energy to existence still filters through. What follows is an embellishment of a scenario I present to my students in questioning their appreciation and understanding of energy supply along with limitations to energy supply.

My breath grows deeper as I trudge up a hill, sacrificing energy to drive my muscles to transport my brain and body around a loop of indeterminate distance. Images of students I knew flit across my mind like reflections against a windshield as it moves across time and space, propelled by fossil fuels. Nothing lingers, only flashes of times and events skim across my mental plate: interactions fall aside as I struggle for a firmer grasp of flitting memories.

As I plod on toward the next bend, my mind begins to wrap around producing answers to simple physiology concepts:

> Q = HR x SV…how much blood is my heart pumping each minute as I climb this hill?
>
> MAP = DBP + .33(SBP-DBP)…how is my blood pressure responding to this work? To what extent have those hundreds of pounds of buffalo wings over the years impacted my cholesterol and blood vessels?
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> VO2 = Q x a-vO2 difference – the Fick equation…how much oxygen am I using to do this work? How many calories am I spending? Enough to justify another plate of wings?
>
> RPP = HR x SBP…How hard is my heart working? How much can it really tolerate?

The physical task at hand makes it nearly impossible for me to drive the focus I need to arrive at meaningful values. Yet, I still struggle with the effort to put numbers to these formulas. While I absorb myself in the math, the perception of my body's work diminishes, as does my sense of the world in which I am jogging.

Abruptly, my mind abandons the dream-state of physiology and crashes into the present labor of my physical being as my surroundings re-emerge.

The sounds of short-legged, snarling-faced, rabid-eyed and gnashing-teethed dogs arise in the present reality: the wiener dog brigade (WDB) has made an appearance and I am its target.

Instantaneously, I face the immediacy of short legs and viciously wagging tails that serve as powerful propulsive forces careening towards me… "pitter patter, pitter patter, gnash, snarl, bark, yip!" My lectures involuntarily flit back into my mind. I pose the question to my students: "Who would you rather be: a marathoner, an ice hockey player, a power lifter, a volleyball player?"

Fear grips me and a pacifist nature binds me. Turning and kicking is not an option. Escape is the only answer. My instruction becomes my reality.

I promptly change course to place distance and direction between me and the WDB. But, the brigade remains in hot pursuit "pitter patter, pitter patter, snarl, yip!, gnash, snarl, bark!"

A rabid, depraved spirit drives them…limitations of my physiology frighten me. Really, what are my chances? Which trained athlete should I be to have the greatest likelihood of safe escape?

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As I charge on, my alternate-self options begin to wane…the power lifter succumbs to the snarling mass (They are great to have around to help you move or to pull an engine from a car, but if you hope they will carry you to safety in the face of a WDB onslaught, you are in trouble; despite all that strength, their muscles are not well-equipped for flight; their mass slows them down, making them an easy target for the WDB.).

The volleyball player is not far behind (If only the WDB were chained up, the volleyball player might be able to leap over, but durable running spirit is not a strength of their tremendous short-term fitness.). As I look over my shoulder, I see the WDB is closing. It's down to my two remaining options: the marathoner and the hockey player.

I continue to charge on and begin to note the warning signs of muscular fatigue and imminent failure building on my muscles. My quads are beginning to burn from acidosis as my glycolysis pathway takes on the burden of providing my muscle fibers with ATP as rapidly as is possible.

My mind strives to refocus: "Am I better off as the marathoner or the hockey player? Damn! How much lactic acid can those wiener dogs tolerate?!"

I push on and chance one last glimpse over my shoulder. The marathoner falls to the wayside, failing due to limited tolerance of such extremely high rates of acid accumulation in the muscles (The marathoner has tremendous ability at covering great distances, but escapism is another story, their muscles just can't deal with such high rates of acid accumulation!).

My mind fills with the rationalization of survival: "I am a hockey player wannabe! I can tolerate the acid accumulation better…it's the nature of what I do."

My legs call out: "REDUCE THE LOAD!" I refuse as the limits of my tolerance rapidly approach.

I transfer, again, back to lecture: "Why is lactic acid produced?" (The answer is to drive the rapid availability of NAD+. This compound permits glycolysis to continue to produce ATP rapidly, but at the same time also leading to rapid lactic acid accumulation. It all boils down to tolerance of lactic acid production in the end). I chant to myself: "So glycolysis can continue to make ATP!"

I try to ignore the downside of this method for producing ATP: acid accumulation and imminent fatigue. Failure.

Yet, even as I give thanks to this pathway for its ability to make ATP so rapidly, the painfully harsh reality surfaces: it also dooms my work capacity on account of the lactic acid production that shuts down the enzymes that drive the glycolysis pathway.

The present re-emerges again. I risk another look over my shoulder just as my leg muscles begin to seize up…they flounder forward in a humiliating display of rapidly diminishing gait control…my pace rapidly falls off against my will…my legs feel as if they are out of my control.

I brace myself for the gnashing little teeth impacting my flesh and for a regimen of physician-prescribed rabies shots. Blood pounds in my ears. My heart seems to want to burst forth from my chest. The "pitter patter, pitter patter, snarl, gnash, bark, yip!, yip!" has stopped!

I turn to re-assess the situation. A handful of wiener dogs snap and gnash at wind currents passing by their tiny heads as their short little quivering legs come to a pensive halt 30 yards back.

Clearly, they were not hockey players. I only imagined myself to be one.

I allow myself to fall back to a tolerable recovery pace and plod on, still working to create a greater distance between me and the WDB. I am thankful for the physiology that enables me to move and that drives me nuts by virtue of appreciating its limitations.

One more bend in the road and I stop. Home. Safe. And still able to produce ATP.

The next time will be another day. I ask myself: "Does their rabid spirit permit the WDB to dream of better success? Will they train? Who will they be next time?"

EXPLANATION OF TERMS:

MAP is mean arterial pressure (the average pressure that the arterial system encounters during a cardiac cycle—filling and emptying of blood from the heart). DBP is diastolic blood pressure (pressure in the vascular system during the filling phase of the cardiac cycle—the heart is re-filling with blood); SBP is systolic blood pressure (pressure in the vascular system during heart contraction—when the heart pumps the blood to the body).

Q is the abbreviation for cardiac output (or flow). It represents how much blood the heart pumps per minute and is a product of SV (stroke volume is the volume of blood pumped per beat of the heart) and HR (heart rate is the number of beats of the heart per minute)

VO2 is the volume of oxygen used by the body each minute (to produce ATP). It is a product of the cardiac output (Q) and the difference between arterial oxygen content and venous oxygen content (it tells how much oxygen was delivered to the muscle and how much oxygen is making its way out of the muscle, thereby telling us how much oxygen the muscle used to help make ATP).

RPP is rate pressure product (heart rate x systolic blood pressure). It helps indicate how hard the heart has to work during any state. It can also imply oxygen use of the heart muscle. If two people do the same task, say walking at 3.0 mph, one person will likely have a higher RPP than the other, indicating that this walking pace places a greater stress on the heart of the person with the higher value. With training and improved fitness, the work of the heart is reduced for the same workload.

Glycolysis. This method of producing ATP is quite rapid and requires the availability of carbohydrate as its sole fuel source. When exercise is very intense, this becomes a preferred method of making ATP. As described, the down-side is when this pathway is running at high rates, it produces lactic acid at high rates and this is widely accepted as a primary cause of fatigue during intense exercise. Two other pathways exist for making ATP. All pathways have their limitations. The marathoner is quite adept at using the aerobic pathway, while the power lifter and the volleyball player will use a bit of glycolysis and something known as the ATP-Phosphocreatine pathway (very rapid, but also extremely limited ATP production capacity). The hockey player requires tremendous involvement from the glycolysis pathway so he/she builds a very high tolerance of acid accumulation.