Comments on Physiology

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For several years now, I have been hearing about possible plans for a transcontinental road race; a head-to-head competition covering some 3,000 miles of distance and over two months on the calendar. I concede that the logistics and the price tag for such an event would be substantial and, combined with other obstacles, make the event a rather unlikely possibility. However, having been tempted with even the slightest possibility, I could not resist giving some thought to how I would go about predicting the winner. So, I began to identify the characteristics that might provide a runner with the best chance of victory in such a race. This study took me through a review of the physiological attributes of top distance runners and how each of these attributes contributes to success at different distances. The following is a summary of the facts and conclusions I came up with in this review.

For shorter races (up to marathon length), it seems clear that the most important physiological characteristic in a distance runner is maximum aerobic capacity. This is a measure of the ability of the athlete to take in and consume oxygen. Because endurance running is an oxygen-dependent activity, the maximum pace that can be sustained by the runner will depend on how efficiently oxygen can be delivered to the tissues. Runners with high aerobic capacity will be able to maintain a much faster pace than those whose bodies have a lesser ability to deliver oxygen.

For example, top marathoners could be expected to have a maximum oxygen uptake (aerobic capacity) of at least 80 milliliters of oxygen consumed per kilogram of body weight per minute (80 ml/kg/min). For a 70 kg (154 pound) runner, this translates into an oxygen consumption rate of 336 liters per hour. Aerobic (oxygen dependent) metabolism is generally considered to produce about 4.8 calories of energy for every liter of oxygen consumed. So, an aerobic capacity of 80 ml/kg/min would produce a theoretical maximum power output of slightly over 1,600 calories per hour. From data in the scientific literature, relating measured power output to running speed for a 70 kg runner, we can estimate that 1,600 cal/hr will produce a maximum pace of about 12 mph. At this pace the runner could expect to complete a marathon in 2 hours and 11 minutes, a time that agrees closely with those recorded by the best runners at that distance. But what about another runner of the same body weight, who has a substantially lower aerobic capacity say a maximum of only 57 ml/kg/min? In this case, the maximum power output would be about 1,150 cal/hr and the maximum pace that the runner could sustain at this power output would be only about 9.5 mph. This runner could expect to complete a marathon in about 2:45 at best.

Of course, an athlete always has the ability to accumulate some amount of oxygen debt from anaerobic (oxygen independent) metabolism during exercise and, in so doing, can increase total power output. However, maximum oxygen debts are typically in the range of 15 to 20 liters of oxygen total. So, with a race of marathon length, anaerobic metabolism could contribute no more than about 5% to total power output. At longer distances, the percentage contribution is even smaller. Clearly, it is primarily the ability to deliver oxygen efficiently to the tissues that makes it possible for an athlete to run typical distance races at a fast pace.

This ability is an interesting combination of heredity and conditioning. Fundamentally, people with high aerobic capacities are born, not made. But conditioning will affect substantially how completely this inborn characteristic can be drawn upon during prolonged exercise. I can

recall once being approached by a runner after a lecture and asked to explain why he was not the top marathoner in his club in spite of the fact that he had the highest aerobic capacity. The simple explanation is that a high aerobic capacity merely gives you the potential to be a top distance runner. Aerobic conditioning is what translates that potential into reality. The runner who questioned me was clearly not training as effectively as his colleagues were. For example, if he had a maximum aerobic capacity of 70 ml/kg/min, but because of inadequate conditioning, could only tap 60% of that capacity, he could be left behind by a runner with a maximum capacity of only 55 ml/kg/min but who had conditioned himself to utilize 90% of that capacity during a race.

So now we have a bit of an idea of what qualities are required to become a top marathon runner. But, are these same qualities essential for becoming a top ultrarunner? And, more specifically, are they what will most likely determine a winner in a 3,000 mile race? To continue our search for an answer, let's look at some typical ultradistances and see how performance relates to prediction on the basis of aerobic capacity. If aerobic capacity were the only factor determining performance in long distance running, then there should be little difference in pace between a top performance at 26 miles and one at 50 or 100 miles. But, the fact is there is a significant decrease in record pace as the distances get longer. The world record at 50 miles, for example, was set at an average 10.3 mph. compared to about 12.4 mph for a record marathon. The best pace ever for 100 miles is 8.7 mph and for 24 hours is 7.1 mph. Obviously something other than aerobic capacity is involved when the races become significantly longer than 26 miles. In theory, an average-sized runner could sustain a championship 100 mile pace with an oxygen uptake capacity of about 50 ml/kg/min. I suspect that there are a multitude of ultrarunners who have aerobic capacities at least that high. Yet, those who can sustain an average of even 8 mph for 100 miles are very rare.

So, if the capacity to deliver oxygen to the tissues is the factor that determines maximum pace in ultradistance running, then it would have to be that this capacity diminishes with distance (or time) run. However, I know of no evidence to suggest that such a decrease actually occurs. It is more likely that aerobic capacity simply decreases in importance as the race distances get longer, and that other factors become more important in determining maximum pace at these distances. At this time, the identification of these possible contributing factors is pretty much a matter of speculation. My speculation is that the primary physiological factor will turn out to be efficiency—biomechanical efficiency, and, with it, fuel efficiency.

Efficiency is probably of minimum importance in a marathon. The time and distance are both relatively short and, like a powerful, gas-guzzling race car in a short automobile race, top marathoners can afford to neglect efficiency in the interest of speed. But, efficiency cannot be neglected in longer races and it probably becomes a primary factor limiting performance as the race distance increases. The other factor that increases in importance as the race distances get longer is good, old common sense. For example, when the distance is long enough that fuel replacement becomes a major consideration, the strategy of fuel utilization and replacement can become the most important factor of all.

In a transcontinental race such as the one I mentioned earlier, the suggested format would require the competitors to run a certain distance (40 or 50 miles) each day, and the winner would be the runner with the lowest cumulative time for the total distance. Thus, every competitor in the race would be out there running a new ultra every day for at least two months. Inability to complete any day's schedule would mean disqualification from the race. Under those circumstances, what attribute would I consider to be the one most likely to make a winner out of one of the participants? Common sense. If I had to take a choice between a highly-talented runner who'

plans to make it on that talent or a back-of-the-pack journeyman who elects to run smart, my money would be on the journeyman. Like the fable of the tortoise and the hare, the prize is not given for being able to run fast—the prize is given for getting there first.