Comments on Physiology

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In ultramarathons, one aspect of conditioning is extremely critical and often becomes the single factor determining the success—whether this be winning or just finishing—or failure of the athlete. I am referring to various aspects of the supply of fuel used to meet the body's energy demands during the race.

To illustrate, let's use, as an analogy, an automobile race. For short race distances, fuel availability is not a significant factor. But, as the distance becomes longer, fuel supply becomes a greater problem. A sleek, powerful, well-tuned automobile will win no races while it sits at the side of the road with an empty tank.

If you were responsible for a car's fuel in a very long distance auto race, you would probably want to consider the following factors:

- the engine's fuel efficiency;
- the kind of fuel that gives the best performance;
- the size of the fuel tank (and the possibility for increasing storage capacity without affecting performance);
- the amount of fuel in the tank at the start;
- the opportunities for refueling during the race.

Long-distance runners, like long-distance auto racers, have to be concerned about fuel supply if they hope to realize the full potential available from the natural ability and conditioning of their engines. Every one of the factors listed above is important to the runner in attaining that potential. To demonstrate their importance, we'll examine each factor, translate it into physiological terms and then see what can be done to apply it in practical situations.

Fuel efficiency

If one has the fundamental physical qualities for distance running, then the single most important natural attribute for running very long distances is high fuel efficiency. Like other natural abilities, fuel efficiency varies from person to person. A typical, average-sized male running at a moderate pace can usually expect to consume about 100 calories per mile. (I weigh 150 lbs. and my energy consumption at a 7:30 pace is 108 cal/mi.) Runners with naturally higher efficiencies have a distinct advantage in ultradistance runs.

Last month I pointed out that in long-term endurance, fuel depletion is the factor most likely to cause limitation or termination of performance. High fuel efficiency delays depletion and so extends endurance. A runner who consumes only 60 cal/mi. will use 3000 calories to run 50 miles. Running at the same pace, a similar-sized runner consuming 100 cal/mi. will use 5000 calories—if, indeed, he or she completes the distance at all.

Type of fuel

In my previous column I compared the relative values of fat and carbohydrate as cellular fuels. The only real value of fat is its abundance; its supply in the body is virtually inexhaustible, even in well-conditioned athletes with very low body fat content. Fat is not a highly effective muscular fuel, and some tissues, notably those of the brain, cannot use it at all for the energy needed for their metabolism. Carbohydrate is the muscles' high-test fuel, and normally the only fuel for the brain.

While fat for fuel is available in the body in almost unlimited amounts, the body's storage capacity for carbohydrates is strictly limited. The body has three reservoirs for carbohydrates which can be used as fuel: 1. glycogen in the muscles, which is used to fuel only the contraction of the muscle cell in which it is stored; 2. blood sugar, which is the primary source of fuel for the brain and certain other tissues which have no fuel storage capacity; 3. glycogen in the liver, which is primarily a blood sugar reserve.

Storage capacity

An average athlete on a typical diet can expect to store about 2000 calories (500 grams) of carbohydrates, mostly as muscle glycogen. The storage capacity of the muscles for glycogen is very diet dependent, however, and can vary a great deal depending on what is eaten. At this point let me emphasize that I am not talking about the practice popularly known as "carbohydrate depletion and loading." For both scientific and ethical reasons, I disapprove of the practice, and perhaps in a later article, I will discuss this in more depth.

What I am talking about here is the natural tendency of the muscles to increase their storage capacity for glycogen when a consistently high-carbohydrate diet is used. In fact, an athlete can experience, on a high carbohydrate diet, a constant 50% increase in muscle glycogen storage capacity over that obtained on a typical mixed diet. For the average person the weight gain for that kind of increase in glycogen storage would be negligible.

Starting fully loaded

The amount of glycogen available at any time is determined by the balance between how rapidly it is consumed for muscular activity and how rapidly it is replaced by the intake of carbohydrates in the diet. If daily activity is very high, the balance will favor fuel depletion, because the replacement of muscle glycogen is fundamentally a very slow process. To restore a fully glycogen-depleted muscle on a typical mixed diet, you can expect perhaps 20% to be restored in the first few hours, but it will require 5 to 8 days for complete recovery.

Like storage capacity, the rate of glycogen recovery is diet-dependent. On a high fat and protein diet it may take 10 or 12 days to restore the glycogen in a fully depleted muscle. This can be reduced to less than 3 days on a high carbohydrate diet.

For a runner whose daily workouts involve consistently high mileage[1] it is unlikely that full glycogen storage will ever be reached, even if a high carbohydrate diet is followed. Unless workouts are significantly curtailed and high carbohydrate intake consistently maintained in the 72 hours prior to competition, the runner can expect to face the starting gun with only partially filled fuel reserves.

Refueling on the run

It has been suggested that ultrarunners should forget about carbohydrate intake during a run, resigning themselves to fat metabolism late in the race, when carbohydrate reserves have been exhausted. Surely we can do better than this abject surrender. It is not only possible to augment carbohydrate fuel reserves during ultradistance runs but, for many runners, such supplementation should significantly extend endurance and shorten recovery. This refueling process probably takes place via blood sugar, but if the run has periods of rest or reduced activity, some initial-phase muscle glycogen recovery may take place.

Recall from my previous column that the body does not need 100% carbohydrate metabolism in order to overcome the limiting effects of carbohydrate fuel depletion. For a runner to be able to sustain initial-level power output, carbohydrate fuel is absolutely essential only for those cells which must function anaerobically (without oxygen). We don't yet know the full extent to which refueling is possible during a race, but every carbohydrate calorie assimilated "on the run" can mean a few more steps without pain or, possibly, injury.

When the race distance is long enough that just "getting there” is a major accomplishment, fuel availability is very important. Any runner who does not implement some fuel replacement nutrition in training and racing is passing up a most powerful tool for extending endurance and promoting rapid recovery. In a future column I want to talk about the kinds of diets that make the most sense for ultrarunners, and develop some simple guidelines for high-endurance dieting.