

## Comments on Physiology

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The cover article in the November 1983 issue of The Physician and Sportsmedicine discussed a problem the authors called "The Muscular Overuse Syndrome in Long-Distance Runners." These authors obtained data on twelve experienced marathon runners at periodic intervals during a 20-day road race. The racecourse averaged 17.3 miles per day (about twice the average training mileage of the runners involved) and the participants had no competition scheduled on days 11 and 12.

The significant observations in this experiment were:

(1) A serum indicator of muscle cell injury was significantly elevated on all test days after the start of the race, except just before the competition on day 13, which followed almost three full days of rest.

(2) Leg muscle soreness was significantly increased after the first day of the race.

(3) Measurements of thigh circumference showed significant decreases by the end of the race.

The conclusions drawn by the authors of this article was that the increase in daily mileage during the race, over that which was typical for workouts with these runners, caused muscle tissue degeneration due to overuse.

Although, for some readers of this column, 17.3 miles per day may not be considered a particularly challenging workout, the observations made in the referenced article should be of significant interest to all ultrarunners. However, I do not buy the authors' conclusion about muscular overuse, and I think it would be worthwhile for us to look at an alternative explanation for the degenerative effects observed in these runners.

I have never agreed with the idea that, within reason, well-conditioned muscles can be injured by overuse as such. That is to say, if you can easily run a 7:30 pace at the beginning of a long-distance race, then a 7:30 pace in the later stages of the race cannot be considered overuse—albeit that your muscles may become injured as a result of maintaining that later-stage pace. If this sounds a bit contradictory, please bear with me. Overuse, as I would interpret its common meaning, means that the muscles were worked beyond their intrinsic limits of capability, given the physical condition of the athlete. I believe, however, that these muscles are intrinsically capable of much more output than they are typically called upon to provide to the average runner in a long-distance race. Overuse, as such, is not the most likely cause when tissue degeneration is observed in well-conditioned runners after highly challenging competitions.

These injuries are the simple consequence of starvation—not general starvation, but starvation of certain tissues for essential fuel. Thus, I believe that the described condition is more aptly called "degenerative fueling." As I have pointed out in earlier columns, carbohydrate in the form of muscle glycogen is the primary, and most efficient, fuel source for muscular work. However, the muscles are limited in their glycogen storage capacity, and both the upper limit of that capacity and the rate at which the capacity is recovered after exhaustive work are totally diet dependent. In effect, then, the size of your body's fuel tank and how fast that tank can be filled depend on what you eat. I have also mentioned that anaerobic (oxygen independent) metabolism uses only carbohydrate for fuel and consumes that fuel roughly 20 times less efficiently than aerobic (oxygen dependent) metabolism. And, depending on your aerobic capacity, even running at slower paces can require a significant proportion of anaerobic metabolism. Thus, rates of

consumption of the body's primary carbohydrate fuel source during distance running can be appreciable.

In addition, the brain's only source of fuel is another form of carbohydrate, called blood sugar. Because carbohydrate is always preferred by the muscles over fat as a fuel, and is absolutely required for all anaerobic metabolism in the muscles, an exhaustion of the muscles' supply of glycogen can put the muscles into competition for the only other available source of carbohydrate fuel—blood sugar—which puts the brain's only fuel source in jeopardy.

Any time it is faced with blood sugar deprivation, the brain takes positive action to restore its supply of this essential fuel. The primary blood sugar reservoir is the liver, where a small amount of carbohydrate is stored for just such occasions. But, in actively competing, muscle-glycogen-depleted athletes, this reservoir is quickly exhausted. Then, the body's last possibility for avoiding brain-fuel starvation is to break down its own tissues and convert their constituent proteins into blood sugar. This is a highly inefficient process, and very destructive to perfectly good and functional body tissues, but it serves a fundamental survival function--the continued supply of fuel for the brain.

So, your body will burn up its own tissues for fuel if you require it to keep going when its primary fuel source is exhausted. And, if carbohydrate fuel is chronically in short supply during repeated days of hard competition, tissue degeneration will become a daily matter of fact. Should we then attribute this effect to muscular overuse? Certainly the muscles are being overused for their fuel supply. But, the primary fault is not with the intrinsic ability of the muscles to endure. The fault is with the supply of fuel with which those muscles have been endowed—an endowment that is totally dependent on the amount of carbohydrate consumed in the diet.

If there is one single point that I have hoped to communicate in this space of the last three years, it is that limited work capacity of well-conditioned ultrarunners is most often the result of fuel deficiency—and that this deficiency is the simple consequence of an inadequate diet. We now have, in the research I summarized here graphic evidence of this degenerative process. Running 500 km in 20 days, these athletes experienced a 10 percent loss in thigh volume. Unfortunately, the authors did not evaluate the athletes' diets during the race, so we are unable to relate the tissue loss to their food intake. And we really don't have enough information to translate that tissue loss into any accurate estimate of total fuel deficit during the race.

However, I'd like to give you an idea of how much tissue breakdown is necessary to produce a small amount of blood sugar, so that you can see how essential it is for you to maintain good carbohydrate nutrition when you are running regularly at long distances. Let's start with 100 grams of muscle tissue. 79% of that tissue is water, 17% is protein and 4% is miscellaneous other substances. So, 100 grams of muscle tissue provides 17 grams of protein—the muscle constituent from which carbohydrate (blood sugar) is made. Conversion of protein to carbohydrate is a very inefficient process, with a maximum 55% yield under ideal conditions. Thus, at best, 17 grams of protein will yield less than 10 grams of blood sugar, a short 10 percent return on the tissue investment. Or, to put it another way, the destruction of one pound of muscle tissue will generate a maximum of 41 grams of blood sugar—enough to run the brain for about 12 hours.

The body will always meet its fundamental fuel requirements because the functions that this fuel supports are essential to survival. If this means burning up tissues—so be it. There is, of course, a less drastic alternative...simply provide sufficient carbohydrate in the diet to meet all the body's requirements for the fuel. Considering the simplicity of this alternative, I remain amazed that so many endurance athletes continue to disdain it in favor of degenerative fueling.