

Comments on Physiology

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For the specialist in energy nutrition, the human population as it is represented in American society today provides two particularly challenging study groups; one consisting of those who need to severely limit their calorie intake; the other consisting of those who need to greatly increase their intake of energy. These groups are, respectively, low calorie dieters and endurance athletes. And, although they are on opposite ends of the spectrum in terms of calorie intake, they do have one very significant thing in common. They both want to be able to accomplish their goals while maintaining their energy at the maximum possible level.

So, in my experience counseling both groups of people, I have found it best to begin by developing a basic understanding of how energy is produced and used in the human body and what happens when that body becomes unable to supply all the energy it needs. In fact, without some basic awareness of energy metabolism, neither group can hope to be able to make intelligently the decisions that are required every day to maintain good health and sustained endurance in the face of extraordinary physiological demands.

For endurance athletes, I have found that energy metabolism is most easily described in terms of the processes of fatigue, because athletes are typically most concerned with what limits their ability to perform. Fatigue can be defined as any completely reversible, work-induced decrease in physical work capacity. As such, fatigue is not a single reaction, but rather a whole series of different physiological processes. And, because fatigue is completely reversible, there has to be a recovery process acting in the body as the reverse of every fatigue process. Long-distance runners who want to know how to combat fatigue in their activity should understand those fatigue processes that apply specifically to distance running. They should also learn about the relevant recovery reactions.

Long-distance running is generally considered to be an aerobic (oxygen dependent) activity. That is, energy demand in this activity is slow enough that the body can continually deliver all the oxygen needed to meet the muscles' oxygen demand. On the other hand, if oxygen cannot be delivered to the muscles rapidly enough to supply all of their needs during exercise, some or all of their energy metabolism will have to be anaerobic (oxygen independent). The muscles will then continue to produce energy at the required rate but will incur an oxygen debt, accumulating lactic acid in the muscles as the currency of the debt. Anaerobic metabolism can generate energy roughly four times faster than aerobic metabolism, so energy production has to be anaerobic whenever the energy demand of the muscle is high.

Fatigue is essentially a limitation in the rate at which muscles can make energy available for contraction. In well-conditioned distance runners, what can cause such a limitation? Barring injury, only one thing can cause it—a change in the availability of fuel to the muscles.

Normally, skeletal muscles have two main sources of fuel available: glycogen, a form of carbohydrate stored in the muscle cells, and free fatty acids, a fat derivative circulating in the blood. For several reasons, glycogen is the better fuel: 1) It is immediately available in the cell for use, while the fatty acids must be transported to the cell. 2) During energy metabolism, oxygen is consumed about 10% more efficiently by carbohydrate fuels than by fats. 3) Carbohydrates are used as a fuel for both aerobic and anaerobic metabolism, whereas fats can be used only aerobically.

If distance running is a completely aerobic activity, then the third property would be in-

significant. But if, even during slow running, some muscles must necessarily produce their energy by anaerobic metabolism, this property becomes all-important to long-distance endurance. In addition, three other properties of glycogen can be very important to a runner's quest for maximum endurance. First, the muscles' storage capacity for glycogen is very limited; second, it can only be used by the cell in which it is stored; and third, replacement of this fuel reserve (the recovery process) is basically slow and very diet dependent.

What about energy metabolism during distance running? Is it strictly aerobic? It's impossible to tell for sure but there are reasons to believe that, even at a slow running pace, some muscles must function anaerobically in order to meet the energy demand required for the total activity.

When lactic acid is generated in muscle cells as a result of the anaerobic oxidation of carbohydrate fuel, the lactic acid is typically transported into the circulation, where it is carried to the liver for removal. If only a few muscles have a high enough energy demand to require anaerobic metabolism, the total amount of lactic acid produced would be small and the overall oxygen debt minimal. In fact, when physical conditioning is good enough that lactic acid removal is very efficient, the athlete's overall metabolism can appear to be aerobic, even though certain muscles may be functioning at a very high, anaerobic energy demand.

During slow running, which of the muscles would be most likely to have such a high energy demand? At a jogging pace, the foot hits the ground with a force of almost twice the runner's body weight. That force must be absorbed by the leg during a contact time of .2 to .3 seconds, and repeated about every .7 seconds. Even though the pace may be slow, the energy required to absorb and distribute that much force at that frequency could be substantial, probably enough to demand anaerobic energy production in those muscles that bear the main force of the footfall, i.e., the muscles of the lower leg.

If these muscles do require such high energy outputs, what will happen when they run out of carbohydrate fuel? They can no longer support anaerobic metabolism, so their ability to generate energy will be reduced by some 75%. If the runner attempts to continue, this high energy demand will have to be assumed by adjacent muscles, those which still have remaining stores of glycogen. But what happens when you put a high energy demand on a muscle that has not been conditioned to endure that kind of load? Pain, and possibly injury.

What is the most common complaint of well-conditioned long distance runners who have overextended themselves? In my limited experience, at least, it is pain in the lower leg. And what causes it? Ignorance. Lower leg pain in properly conditioned runners is the very predictable consequence of malnutrition.

As long as runners persist in believing that all they have to do to be effective is put in their mileage; as long as they continue to willingly accept pain as an inevitable part of their lifestyle, then they are going to have pain and they are going to be less effective runners than they could ideally be. No race car driver would take the track on race day without a full fuel tank, and he certainly wouldn't put coal oil in the tank of a car that runs best on high test gasoline. It is a mystery to me how so many runners remain unable to apply this simple lesson to their own bodies.

In future articles I will outline the simple logic of effective fuel replacement nutrition and I will provide some guidelines for distance runners to use in getting the most out of their food calorie intake.