

Comments on Physiology

Richard E. Ecker, Ph.D.

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In past articles, I have tried to point out the importance of dietary carbohydrate as an essential source of fuel for long term endurance. So far, these discussions have centered on the use and replacement of muscle glycogen, the primary fuel for muscular activity. There is, however, another aspect of carbohydrate fuel economy which has a significant influence on physical endurance. This is the supply of fuel for the brain.

The brain is a very demanding organ, in terms of both the amount and the type of fuel it will use. And, of course, because this organ is the control center for all of the body's activities, an exhaustion of its supply of fuel could be expected to have very serious consequences. In fact, the brain has at its disposal a variety of mechanisms to assure that its fuel supply does not become dangerously depleted. One of these mechanisms *the involuntary cessation of muscular activity*—or what has become popularly known as "running into the wall.

Unlike the muscles, the brain cannot store away fuel for use at a later time. Nor can it draw from the body's main reservoir of stored fuel—fat. Except during starvation, the brain is completely dependent on blood sugar to provide fuel for its constant energy demand.

Blood sugar is produced from the digestion and assimilation of carbohydrate foods from the diet. All dietary carbohydrates are composed of simple sugars, primarily glucose (or dextrose as it is sometimes called). Carbohydrate digestion causes an increase in the amount of glucose being carried by the blood. This blood sugar can be used in a number of different ways, depending on how much is available and what specific needs the body has at the time.

It is used to replace muscle glycogen that is consumed during muscular activity, or to restore liver glycogen which itself serves as a blood sugar reservoir. If it cannot be used expediently for other purposes, or it is produced so rapidly that the body has no other way of disposing of it in a reasonable time, much of it will be made into body fat. But, whatever other functions it may serve in the body, a minimum level of sugar in the blood must be maintained in order to assure a constant and adequate supply of energy for the brain.

If this minimum blood sugar level is not maintained, the body will initiate a series of defensive reactions, all intended to guarantee that the brain will not be deprived of this essential source of fuel. Among these reactions are the hunger response, the release of sugar stored as glycogen in the liver, the conversion of dietary proteins into glucose and, under prolonged carbohydrate deprivation, the body will even break down its own muscle tissue to be converted into carbohydrate fuel for the brain. A depletion of blood sugar can also cause a number of unpleasant and potentially detrimental physical responses, including headache, nervousness, mental confusion and physical fatigue.

Because carbohydrate is the preferred fuel for muscular activity, periods of very intense or very prolonged physical effort can cause an extreme drain on the body's total stores of carbohydrate fuel. When these stores become very low, the brain finds itself in competition with other tissues of the body for the limited amount of carbohydrate that remains available. When blood sugar is monitored in athletes during long-term physical activity, it decreases constantly as the activity progresses. However, the brain cannot permit itself to become starved, so it reacts decisively when its fuel supply is seriously threatened. The most severe action it can take is loss of consciousness. Short of that, it will eliminate further competition for fuel by summarily terminating muscular activity.

Terminal exhaustion in endurance athletes is not a muscular problem—it is a central nervous system problem. It is a direct consequence of a depletion of the brain's supply of essential fuel. Years ago this fact was established by a simple experiment in a Scandinavian laboratory. And, I'm sure, it has been confirmed unknowingly by a multitude of ultrarunners in the years since. These scientists discovered that completely exhausted athletes always had very low blood sugar levels, and could resume their assigned workloads very soon after being given a small amount of glucose to eat. The evidence suggested that this small amount of glucose had elevated blood sugar levels enough for the brain to release the muscles for continued activity. Similarly, I have heard reports from ultrarunners who have become totally exhausted, only to find their endurance restored by nothing more than eating a cookie.

Physical exhaustion begins and ends with carbohydrate fuel deprivation. It begins with the depletion of glycogen reserves in the muscles, becomes critical with the depletion of glycogen stores in the liver, and ends with the depletion of sugar in the blood. If you want to avoid letting "the wall" come between you and the end of an important race, make sure that you don't start the race with half-full carbohydrate fuel reserves. And, if the race is extremely long, learn how to eat on the run.