body's major fluid compartments.

Glycerol-Water Benefits

The larger the fluid compartment, the more it will expand with glycerol infusion. All three compartments identified above contribute fluid to sweat, especially the extravascular. Since most of the absorbed glycerol-water combination moves into the extravascular compartments, little is lost via the kidneys because of minimal stimulation of the receptors that maintain plasma volume. The plasma volume is the smallest of these compartments, but percentagewise its contribution to sweat is the largest. Thus, glycerol-induced hyperhydration through expansion of the extravascular compartment provides a reservoir for maintaining plasma volume as fluid losses from sweating continue. In turn, this keeps the skin surface of the body cooler, maintains cardiac output, and delays the onset of fatigue. As the glycerol is metabolized during the period which includes the race or long training session, its osmotically bound water also becomes available to maintain the steadily decreasing blood volume. Glycerol is metabolized to dihydroxyacetone phosphate, which is part of the metabolic pathway for glucose, and thus forms another energy source.

Research studies involving the use of glycerol for runners in training or competition are not extensive, but some results are sufficiently encouraging to indiate a potential benefit. One well-known study, results of which were published in the prestigious journal Medicine and Science in Sports, (April 1990) was conducted in the laboratory of Marvin Riedesel at the University of New Mexico during the late 1980s. A half dozen recreational runners recruited from the Albuquerque area each agreed to do three 90-minute treadmill runs in a hot humid room over a several-week test period using three different fluid-replacement regimens. During one of these runs, they were permitted to drink only a small amount of water, with a similarly small water portion provided prior to the run. During another of the runs, they drank plenty of a water-orange juice mixture, and were permitted to drink a sizable amount of this before their run as well. During the remaining run, the water-orange juice mixture was supplemented with glycerol to promote fluid retention and redistribution of fluid through the body fluid compartments.

Physiological responses were sought which might indicate that the runners who hyperhydrated with glycerol and then drank adequate glycerol-containing fluid during the run, were in fact *protected against heat injury more* than under the other two circumstances. When little fluid was ingested, not only was there little urination (the kidneys were retaining what little fluid was available), but also the body temperature rose considerably. When plenty of fluid without glycerol was ingested, urination was considerable, and the body temperature also rose. When fluids as well as glycerol were ingested, urination was less, but body temperature was also not so high, suggesting that glycerol was helping to redistribute the water throughout the body, and that plenty of fluid was available for use in evaporative cooling. Since that study, we have suggested the use of glycerol to several of our elite-level marathon runners selected to national teams competing in hot weather. Our experience with marathoners at both the Tokyo World Championships and the Barcelona Olympic marathons suggests that *pre-race* hyperhydration with glycerol water can be very beneficial as an accompaniment to during-race drinking for helping to maintain adequate fluid volume.

The Recipe: 26 to 1 Ratio

An optimum amount of glycerol and water ingestion, which seems well tolerated in terms of no gastrointestinal discomfort and an adequate level of hyperhydration, is 1 gm glycerol per kg body weight mixed with 21 ml/kg body weight of water. It is easily obtainable from a local pharmacist; no prescription is needed. Glycerol is heavier than water (density of 1.26 gm/ml compared to water at 1.00). Thus, 60 gm of glycerol occupies 47.6 ml of volume, whereas 60 gm of water occupies 60 ml of volume. The 'recipe,' then, for preparing a glycerol solution would be something like the following: a 60 kg male distance runner (132 pounds) should add 60 x 21 = 1,260 ml water to 48 ml of glycerol (26.25 to 1 ratio), mix it, and then ingest it over a period of 1 to 2 hours pre-marathon or pre-long-training-run. (About 300 ml of water can be replaced by electrolyte drinks to add some flavor.) A female distance runner weighing 50 kg (110 lb) would prepare a solution containing 50 x 21 = 1,050 ml of water mixed with 40 ml of glycerol (also 26.25 to 1). Metric measuring utensils can now be found in most grocery stores or pharmacies as a result of the nation's continuing progress with metrification.

Practice, Practice, Practice

The strategy for using glycerol during conditions of long training runs (30 km or more) done in warm weather has at least two important facets. **First**, it is under these conditions where sufficient fluid losses will occur that the benefits of glycerol loading will be best perceived. For short training runs or races, done during cool weather, fluid losses are not large. **Second**, gaining experience during training provides the kind of practice that is essential if the technique is to be used before an important hot-weather race. It is a cardinal rule *not* to try anything during races that hasn't been well tested during training. New shoes and clothing should be broken in, new pacing strategies ought to be tested, and here as well, plenty of experience during training sessions is essential. Important questions need answers, and these can be obtained only through experience. How long will it take to drink the glycerol-water mixture comfortably? How long before the run (or race) will be required before the fluid has cleared the gastrointestinal tract? Is it more palatable when mixed with electrolyte beverage? Will there be a bloated feeling, and if so, how long after drinking, to permit its accommodation? It is essential to ensure that not only the required volume of fluid can be consumed, but also that gastrointestinal comfort with this pre-race procedure is minimal.

Some final caveats about fluid intake during training and racing in the heat come from the laboratory of Carol Gisolfi at the University of Iowa, also reported in Medicine and Science in Sports and Exercise (March 1993). One relates to the temperature of ingested fluids. While fluids at a cooler temperature do help to cool the body, this is not as important as ensuring that fluids are indeed taken in, whether warm or cool, because it is their evaporation that provides the larger cooling potential. Second, pre-hydration with water or water-glycerol does *not* mean that it is unnecesaary to drink during the run or race. It is also very important to drink *during* the activity because of the much greater net losses of fluids. And finally, if there is a choice between drinking and splashing water over the head, although the latter probably feels better, the former will provide ultimately more cooling.