Ergonomics

Physiology of Cyclist Power Production

John Forester

The statements on the physiology of cyclist power production by David Gordon Wilson and by Crispin Mount Miller (December 1982 *Bike Tech,* Volume 1, Number 4) illustrate the misconceptions caused by current assumptions of exercise physiologists. At least those authors recognized that a problem existed and asked for answers.

Exercise physiologists measure oxygen efficiency and make much of it. They require a cyclist to ride at 25 mph in a 140-inch gear, because that is the most oxygen-efficient gear, and wonder why he collapses in ten minutes. So what? Any person looking at actual road racing and endurance cycling data and techniques must conclude that the hypothesis of oxygen efficiency is at least irrelevant. Successful cyclists ride at oxygen-inefficient cadences, a fact for which a new hypothesis must be created.

I propose a new hypothesis which considers instead the acquisition, digestion, storage and use of food, the other side of the chemical reactions that produce power.

Power is force times speed. The speed of muscle contraction (within the range of cycling cadences) has little effect on muscle performance, but the force has considerable effect. Low forces are developed by only the aerobic muscle fibers, while large forces require both the aerobic and the anaerobic fibers.

The aerobic fibers are powered by blood-carried glucose and triglycerides; the anaerobic fibers by muscle-stored glycogen. Blood-carried glucose can be replenished during cycling, first from the liver and then by eating carbohydrates. Blood-carried triglycerides and fatty acids are practically inexhaustible because they come from body fat, but the rate at which fat can be converted to them is relatively inflexible. Hence most of the fuel for high-power long-duration exercise is glucose, because the triglyceride and fatty acid production rate does not climb much during a few hours of exercise.

Muscle-stored glycogen cannot provide much of the energy for road racing and endurance cycling, because it cannot be replenished during exercise and the supply lasts for only about ten minutes of hard exercise. Glycogen is merely polymerized glucose, taken from blood glucose and polymerized in the place of use so it won't get loose. The body will not take glucose from the blood for storage in the muscles when exercise requires that the glucose be used directly to power those muscles. Muscle glycogen is replenished largely during sleep, and it takes two nights to fully replenish the muscle-stored supply after exhaustion.

Therefore it is impossible that muscle-stored glycogen can be a major factor in events lasting from one hour to many days, but it can be a winning factor if properly used. This is not a contradiction, as I will explain.

Since anaerobic work can supply only a small portion of the energy needed for an extended event, the successful cyclist arranges to spend most of the event using only his aerobic fibers, supplying the glucose fuel first from his body stores and then from food he eats during the event. Sparing the anaerobic fibers conserves the muscle glycogen for the critical parts of the event, when high-power short-term sprinting to surmount a hill, make a break, or win a sprint provides the winning margin.

Using only aerobic fibers means using low muscle forces to avoid recruiting the anaerobic fibers and using glycogen. For a given level of power, low muscle force requires high muscle speed, and therefore high cadence. This strategy is so advantageous that the cyclist adopts it even though it requires more oxygen, and in the end more food. (Why else would experience have shown that winners waste time and effort eating?) Spinning on glucose keeps the cyclist in contention with sprint power in reserve, while sprinting on glycogen gives him the winning advantage.

Triglycerides and fatty acids have their importance, too. It is practically impossible to eat sufficient carbohydrates for complete replenishment of glucose during longer cycling events. Cyclists who are successful in 24-hour and multi-day events have trained their fat-metabolic processes to operate at higher-than-normal rates day in and day out. Thus they obtain a higher proportion of their "normal" power from fat conversion than do less highly trained cyclists, so that for a given level of carbohydrate intake they produce greater power, and can keep it up as long as their body fat lasts.

It is my opinion that training this system is the most painful experience for a cyclist, for only by forcing himself to keep going after his normal stores have been used can the cyclist "convince" his fat-metabolic processes that normal living involves damn hard work for days on end.

For a more complete discussion, including related hypotheses (on bicycle design and proportions, implications of neurological function for cycling, and why exercise physiologists have missed the point), see the chapter on The Physiology of Hard Riding in my book *Effective Cycling,* to be issued by The MIT Press during spring, 1983.

Letters

Striving for Stability

I've been enjoying *Bike Tech* and want to send encouragement to keep up the good work. I especially liked the "Balancing and Steering" piece in the August 1982 issue.

I hope you continue to look into questions regarding handling. I've designed and built a couple of frames and find frame design to be both an interesting and complex subject.

I'd particularly like to see some treatment of wheel flop. I realize that the handling article by Whitt and Wilson represents only part of their work and that they probably talk about wheel flop. But this particular article could lead to the conclusion that bicycles with the same or near same stability index handle alike. I don't think that's true. A bike with a shallow head angle, such as 70 to 72 degrees, wants to "dive" into corners more than a bike with upright angles.

I hope you'll also address the question of wheelbase. It's been my experience that wheelbase is not nearly so important as head angle and fork rake. And we're seeing that in some Italian road bikes made to be comfortable over long distances with longer chainstays, but also made for fast handling with 74-degree head angles and shorter fork rakes.

It seems that some so-called touring bikes could do with higher stability indexes. Bicycling is, of course, a tradition-honoring sport and it seems that touring machines often are made with shallow head angles and longer fork rakes because they're supposed to look that way. On fast, downhill runs, however, that can mean a squirrelly ride on a loaded bike. Whitt and Wilson say that Stability Index values from -1.85 to -2.3 "give lighter, more responsive steering." I translate that as meaning that they're difficult to control on fast downhill runs, especially fast corners. The whole style of "touring geometry" most likely started with riders and framebuilders looking for comfortable machines to handle long-distance tours over rough roads. They found, of course, that more fork rake and shallower head angles transmitted less road shock. I don't think handling really was a consideration.

But you're the guys with the answers. I'd like to see some more handling stories to find out if my gut level reactions to frame geometry and my experience, building and riding bikes, are correct.

Incidentally, I think the values for Fork-offset ratio in Table 1 in the Whitt-Wilson article were incorrect. They should decrease as head angle steepens and stability index increases. (See corrected table in the letter from Brad Butler. — Editor)

One other subject that might provide an interesting story is maximum cornering an-