

Bicycle Medicine & Science

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The true method of knowledge is experiment.

William Blake, 1788

What's New This Past Year

What's the latest medical and scientific info about bicycling?

Do you read the ad copy in the magazines to figure out what might be worth trying? Do you look to the pro athletes, who are sponsored, and figure that if they do it or use it, it must be great? Do you ask your friends? Or do you just spend your time, effort, or money and try everything yourself?

For most of us, it's a combination of all of the above, plus a little hope. And, unfortunately, that little hope is what lots of companies cash in on when they manage, for example, to sell us plain old water at a couple of bucks a gallon or more.

Scientific method: There's another way—the scientific way. Looking at what studies or experiments really show. The scientific way is the best way to evaluate what works and what doesn't. The scientific way is better than opinion or guessing, but it's not foolproof. Unfortunately, there is sometimes bad science.

A complete review of what makes good science isn't possible in this article, but here are a few examples of "science" problems.

(For a more complete review of the subject read: Ergogenic Quackery: Maxxta Makes You Fasta, in *Bicycling Medicine*, published by Simon & Schuster, 1988.)

Initially, only studies showing an effect tend to be published: Few publications are interested in reporting, for example, that Vitamin X doesn't cure cancer. Once something has been accepted as working, then it's fair game for challenge. So it's common for some substance or training method to burst on the scene for a few years, and then have its bubble burst—by being shown not to work or having undesirable side effects. Chromium, bee pollen, and royal jelly, for example, have been left behind. Creatine is on the bubble.

Some studies are paid for by an interested party. It's often difficult for the lay reader to ferret out this information. This year, for example, peanuts were reported to help ballet dancers' performance (presumably by increasing their deficient caloric intake) in a study paid for by a consulting company. A company I'd guess was representing a peanut company. Peanuts may well help calorically deficient ballet dancers, but so might Häagen-Dazs ice-cream or Pop-Tarts.

Worse, imagine a company that pays for 10 studies from 10 different sets of researchers and advertises only the findings, perhaps obtained by chance, that promote the company's products.

Some studies appear to provide important or new information but the wrong question is being asked or answered. The recovery drink R4 was shown to provide better recovery than Gatorade when 24 ounces of either was consumed between taxing exercise bouts. Sounds promising, doesn't it? But the R4 provided almost four times as many calories. Would a couple of donuts with the Gatorade have been as good?

It's also common for studies to show apparently conflicting results. For example, over the years bicarbonate loading and caffeine have been accepted as improving human performance. Newer studies have questioned that conventional wisdom. Each study often adds just a little piece to the puzzle. It's important not to put too much faith in any one study.

I've written similar articles the last few years. I've culled over 2,500 reports and studies during the last year. Here's my synopsis and spin on some of the published information on bicycling-related medicine and science that came out in 1999.

Each new paragraph represents a different study.

Nutrition

Calories

Pre-event nutrition: Carbohydrates at a dose of 9 grams per kilogram (g/kg) per day provided no advantage over 6 g/kg/day when carbohydrates were also consumed during exercise in a 100-kilometer time trial.

In another study, carbs did provide more glycogen stores at 9.5 g/kg vs. 7.5 g/kg but no difference in performance: This time trial was probably not long enough—just 15 minutes.

Little difference in 100-kilometer cycling performance was found after 13 days of a mostly fat diet, 13 days of a mostly carb diet, or 2 days of mostly carb after 11 days of a mostly fat diet.

Another study showed better performance when a high carb diet followed a fat diet than when a high carb diet was maintained.

Three hours before testing, runners consumed 750 calories, either 37% carbohydrates, or 93% carbs. They ran about 20% longer on the carb diet.

Three hours before a mountain bike race, either 1 g/kg or 3 g/kg of carbohydrate were ingested. Although first lap performance was slightly worse, overall performance was 3% better (about 3 minutes in a 90-minute race) with the 3 g/kg carb meal. Perhaps the extra carbs helped. Or perhaps the higher carb group had a better pacing strategy.

During event nutrition: About 25% of carbohydrate needs can come from glucose ingested during exercise.

Studies of ultratriathlon and ultramarathon athletes showed that nutritional intake is heavily dependent upon what the organizer provides at aid stations; regardless, carb, fluid and especially sodium replacement is inadequate to keep up with demands.

No difference was found between carb gels and glucose solutions in blood tests of glucose biochemistries.

Several studies again showed that carbohydrate ingestion during aerobic or aerobic/anaerobic activity of an hour or longer duration improves physical and mental performance.

Higher carbohydrate intake was associated with decreased symptoms of overtraining.

Post-event nutrition: A carbohydrate meal of 0.8 g/kg/ each hour for 5 hours was not nearly as good as the addition of half as much—0.4 g/kg—protein. But half again as much carb (for a total of 1.2 g/kg) was even better. (We're talking about recovery after an at least several hours exhaustive road race. If you are 143 pounds, the best glycogen replacement resulted from a little more than 300 calories of carbohydrates every hour for 5 hours.

R4 was found to be better than Gatorade for some measures of recovery. But the study, which is used to promote the product, doesn't tell the whole story. Almost four times as many calories of R4 were given—560 calories from R4 vs. 150 calories from Gatorade. The study was funded by the manufacturer.

MCTs: Three years ago Van Zyl reported that medium chain triglycerides could improve performance. Promotion and marketing of these products quickly followed. An effort this year to reproduce these results failed: Addition of pre-exercise MCTs didn't help performance.

Hydration

The addition of carbohydrate to water post exercise reduced subsequent fluid loss from the kidneys and so helped rehydration. An 8% carb solution was not better than a 6% solution.

Sodium-free solutions worsened serum sodium: Beverages containing sodium are recommended.

Hydration backpack systems were associated with slightly better hydration and performance than traditional frame-mounted bottles—in a mountain-bike study funded by Camelbak.

Fluids that taste good are more likely to be consumed. Palatability changes depending upon hydration status. (What tastes good at rest doesn't taste the same when tired, hot, sweaty, and exercising.)

Vitamins and Minerals

Iron: Iron deficiency without anemia did not impair endurance performance.

Antioxidants: Although they may improve certain blood markers of immune function,

whether this translates to a health benefit is uncertain.

Ergogenics

Performance-enhancing substances and devices.

Should these be banned? Should one be allowed to take something to make one stronger or go faster? It's not a black and white issue, and not a question that I'll discuss here. But many researchers are looking at these substances.

Supplements are used by over 90% of athletes in some sports. A study of college athletes showed important deficiencies in knowledge about supplements. In the case of vitamins and minerals, intakes over 10 times the RDA are common. (As I point out in my book *Bicycling Medicine*, studies have shown that such excessive RDA intakes are more likely to hurt, rather than help, performance.)

Supplements, unlike drugs, do not have to be proven to be safe and effective before they are marketed. There are no governmental regulatory processes unless a substance is shown to be dangerous. The FDA issued warnings this year about a number of supplements, marketed as sleep aids, aphrodisiacs, and muscle builders that have caused at least three deaths and hundreds of severe reactions. Some of the brand names include Revitalize Plus, Serenity, Enliven, GHRE, SomatoPro, NRG3, Thunder Nectar, and Weight Belt Cleaner. The diet-pill company Metabolife is being sued for its (legal, unregulated) use of ephedrine in its products—a substance linked to seizures, brain damage, stroke, and as many as 17 deaths,.

5-Hydroxytryptophan (5-HT): Had no effect on cycling performance.

Anabolic steroids: A review found a strength improvement, even in relatively low doses.

Androstenedione: No effect on testosterone levels. May convert to estrogens. (Bad for men—cartoons showed Mark McGwire with breasts.) May be associated with increased heart attack risk.

Antidepressants: Some believe these medicines may help performance even in the

absence of depression. No effect in a 90-minute time trial of seven non-depressed male cyclists.

Beta-carotene: Improved 5-kilometer running performance in one study.

Beta-hydroxy-beta-methylbutyrate (HMB): No help in strength training.

Caffeine: Helped Wingate cycle (an anaerobic test) performance. Helped 30-second running sprints, regardless of whether a regular coffee drinker or not.

Creatine: For the last few years creatine has been one of the hottest ergogenic aids. Over the years, the consensus has been that it will not help aerobic performance activities such as most cycling events. It may or may not work for sports with repeated anaerobic efforts such as track cycling, hockey, or football.

The current consensus is that if taken, creatine should be ingested along with glucose. Some studies seem to indicate that carbohydrate supplementation alone may increase performance as much as creatine.

Creatine is not without potential side effects:

- Creatine may be a problem in the heat—it may be related to cramping and injury. Some studies show this, others don't.
- It may increase blood pressure.
- Creatine seems to increase body weight—probably not good for climbers.

Studies this year found that maintenance dosing should be continued if benefit is to be sustained.

Studies this year also showed that creatine:

- Failed to increase anaerobic power output during cycle sprint bouts in two separate studies of well-trained male cyclists.
- Did not change Wingates (an anaerobic test) in another study.
- Did not enhance swimming performance in one study, did in another two.
- Did not help rowing performance.
- Helped football players riding a bicycle.
- Helped repeated hand grip exercise and hand cranking.
- Improved strength training (in a study funded by creatine distributor).
- Helped maximal quad contraction in women.

- Did not enhance strength gains in high school athletes.
- Did not affect muscle strength in other.
- Did not increase muscle size in trained individuals.
- Delayed neuromuscular fatigue.
- Did not change phosphocreatine utilization during moderate- and low-intensity exercise; did change phosphocreatine utilization during high-intensity exercise.
- Attenuated the effects of reduced strength during dieting.

Cycling summary: Creatine may or may not help track sprinters. It probably won't help anybody else.

Ginseng: Two studies showed no performance benefit.

Glutamine: No effect on performance or weight loss. Role in immune function, if any, being investigated.

Pyruvate: No help.

Salbutamol: This common asthma medicine helped an about hour time trial whether cyclists were asthmatic or not.

Chiropractic, massage: Chiropractic and massage were studied for a possible aerobic benefit: none was found.

Equipment

Sport bras are not created equal. A study showed significant differences in terms of comfort, support, displacement, and psychological fit. Overall, Moving Comfort was the best and Danskin and Hanes the worst.

Dual-suspension mountain bikes are promoted as increasing contact with the trail. It has been suggested that they may improve rider economy. Not so in a study this year that showed lower heart rates and VO₂ when riding front-only suspension bikes.

A study of *mountain bike suspension forks* showed that they reduced horizontal braking impulses and forces when compared with rigid forks.

A heat-clothing study found no performance difference between 100% cotton and 50/50 cotton/polyester T-shirts on a treadmill. Was the

right question asked? This was a lab study and no accounting was made for real-world evaporative cooling due to travel through air. (Last year *Coolmax* was significantly cooler than a number of other fabrics studied.)

Three more studies this year showed no help in physiologic performance measures with the external nasal dilator *Breathe Right*. The strips do increase nasal flow—but aerobic athletes such as cyclists breathe through the mouth when working hard.

Almost all racers now use *clipless pedals* for comfort. A study this year found them not to offer any physiologic performance advantage over toeclips and straps.

A study in runners showed that at high levels of exercise many *heart rate monitors* were unreliable—possibly due to the loss of stable electrode contact. Another study specifically showed that the Polar brand was accurate in arm-crank exercise.

Head injuries claim about 1,000 cyclists lives a year in the U.S. Bike *helmets* have again been reported to reduce head injury deaths by about 85%. Approximately 50% of riders infrequently or never wear helmets.

A study this year found that the portable *Accusport* blood lactate analyzer measuring device met the criteria of the FDA for values accurate to 0.75 mmol/L. Although medically acceptable, I haven't found it to be worthwhile in my coaching practice. If a threshold occurs at 4.0 mm/L, a value of 4.5 may not seem far off. But think of time trialing. A heart rate of 170 is a lot different than a heart rate of 190, but that's the same percentage difference—and less than the percentage difference the that FDA finds acceptable. A heart rate monitor that can't discriminate closer than 20 beats per minute is almost useless. In most people's hands, the strict technique required makes the Accusport even less reliable.

The *Tune* power meter offers potential as a training and coaching aid. It has been demonstrated to be reliable and valid.

Climate

Heat acclimation failed to improve 40-kilometer time trial performance at moderate temperatures.

Part of the adaptation to heat is an increase in blood volume. One study that looked at the effect of expanding plasma volume (the fluid, or non-cellular part of blood) found an improvement in performance. Another contradicted that study and found no change.

Pre-cooling has been studied. It lowers temperature at the start of an event. Studies are mixed as to whether pre-cooling improves performance.

Physiology—General

A cycling study again showed that blood lactates while time trialing are between 5 and 12 mmol/L, well above the so-called anaerobic threshold. A rowing study also confirmed this: 30-minute blood lactates were significantly higher than all “lab” thresholds commonly accepted.

Lactate levels in a lab were shown to have little reliability in predicting cyclists responses to “free-range” riding.

Active recovery between 30-second anaerobic efforts did not promote the greater disappearance of blood lactate than did passive recovery.

There isn’t much in the way of a predictable relationship between anaerobic threshold and heart rates in different sports—so thresholds must be sport-specific.

Cyclists in a 12-hour endurance mountain bike event averaged 70% of maximum heart rate.

Physiology tidbit: Time trial threshold—the heart rate at which cyclists time trial—is similar to that heart rate level at which firefighters work in a burning building or Formula One race-car drivers compete.

Although biochemical markers for overtraining exhibit variability and are not generally accepted, a study that looked at some of these markers found two weeks was not as good as five weeks for recovery from eight months of intense competition.

Physiology—Muscle

Training was shown to enhance the ability of muscles to accumulate glycogen.

Running out of glycogen? This storage form of carbohydrate energy is used differentially in different muscle types. Riding steadily depletes energy stores in type I muscle fibers. Intermittent high power output results in type II muscle fiber energy-store depletion. (There are physiologic reasons why it is possible to have a sprint left, but not be able to keep pace; or conversely, be able to keep pace but not have a sprint left.)

Read more about muscles in the training section below.

Physiology—Blood

Hematocrit is the percentage of red cells in a given volume of blood. *Hemoglobin* is the amount of that oxygen-carrying protein in a given volume of blood. The *total blood volume* is made of cells (red and white) and *plasma*—the cell-free fluid. *Red cell mass* is the total amount of red cells in *all* the blood of a person.

The acute effects of both a half-Ironman triathlon and a six-day stage race were that hematocrit and hemoglobin decreased—thought to be mostly due to an increase in plasma volume. The practical expectation is that (barring doping) exceeding the UCI 50% hematocrit limit is more likely at the beginning, rather than during or at the end, of stage racing.

Human performance is more closely related to blood volume and red cell mass than it is to hemoglobin or hematocrit.

The effect of 30 days of EPO administration was maximal at the end of the doping month. Its effect on VO₂ max lasted at least four weeks, but was only half as much at the end of the four weeks as it was immediately after the month of injections.

Physiology—Gastrointestinal

Stomach emptying of a half quart of a sport drink was reduced during highly-intensive intermittent exercise (rugby). But more than 80% was still emptied (vs. 90% at rest) showing that fluid ingestion during exercise is still an important and effective strategy.

About 60% of Ironman participants experienced gastrointestinal distress during the event, perhaps in part due to an increase in gastrointestinal permeability.

Physiology—Lung

In some cold-weather sports more than 50% of National and Olympic teams have been found to have exercise-induced bronchospasm or asthma. Almost 75% of those with competition exercise-induced bronchospasm/asthma could not be diagnosed with standard lab tests and required in the field evaluation.

Dehydration worsens exercise-induced bronchospasm.

At high work levels, blood flow to intercostal muscles (chest muscles between the ribs which are involved in the work of breathing) was shown to be insufficient to meet demand. One implication may be that training of breathing muscles may be necessary for high-level work.

Lung ventilation can limit work at near maximal and maximal work rates. A study showed this may be related to fluid in the lungs.

Physiology—Women

What are the fitness parameters of elite female cyclists? Reported Australian and American figures showed their VO₂ max to be about 64 ml/kg/min. Average power output during a 30-minute time trial was about 260 watts—about 80% of ramped peak power.

In a study of women aged 20 to 47 there was no relationship between age and VO₂ max.

The menstrual cycle did have a role to play in VO₂ max (about 2.5% variation), but time to exhaustion on a max test was the same—so the practical implication is that performance doesn't change.

Training/Racing

Pacing: Cyclists completed a flat 20-kilometer time trial and average power was determined. Cyclists were later tested where the first four minutes of the time trial were performed 15% below, 15% above, and at previous average time trial power. The best times were with the slow start.

I've written before about the importance of establishing a *breathing rhythm* in hard, steady riding (climbing and time trialing). Studies this year also showed such rhythms help experienced athletes in other sports.

What is the optimal *cycling cadence*? With power output held constant, perceived exertion was lower with increased cadence. Studies in the past have found that faster cadences increase heart rate and the work of riding at a given power output. But muscle fiber tension is lower at faster cadences, and that seems to be important.

Should you train fitness systems *concurrently or sequentially*? A study of well-trained cyclists found the end result was the same. Sequential aerobic and anaerobic training was, in the end, as good as concurrent aerobic and anaerobic training. But the latter group showed earlier improvement—and presumably would race better in the middle of the four-month training period.

Which is more important: *volume or intensity*? A study looked at marathon runners and found either approach equally successful in improving marathon times in moderately-trained runners.

In a group of sub-elite cyclists, 15-second sprints to exhaustion improved VO₂ max more than continuous incremental exercise to exhaustion.

Tapering for important races remains an art as well as a science. Standard advice is to reduce volume, but not intensity. One study of a seven-day taper found that time trial performance was better with a 50%, rather than with a 30% or 80%, taper.

It used to be said that the bent-over *aerodynamic position* reduces lung function. I remember coaches saying: "Sit up, open up the lungs." Studies again this year confirmed that bent-over riding does not increase the work of breathing. (By closing the hip angle it does reduce leg muscle power in riders not trained in this position.)

Some coaches suggest training near lactate-threshold intensity (4 mmol/L). Many others avoid this area, feeling it too hard or too easy.

Ads tout that Spinning® uses 500 fat calories in 40 minutes. A study showed only 159 fat calories burned for a group of ten riders whose

weight averaged 166 pounds. Lighter participants will use even fewer fat calories.

Freeweight circuit training is inadequate to stimulate cardiorespiratory fitness.

Strength training: Does strength training help cyclists? Many coaches insist that strength training is crucial to cycling performance. Many others state strongly that strength training is a waste of time. Others think it may worsen performance. Studies have consistently showed that strength training helps strength. (Sports scientists use the term *strength* to refer to 1-rep max—the maximum weight that can be lifted once.) But does improved leg strength help cycling performance? Is arm strength or core body strength important? A lot of food for thought about these and other strength-training questions in studies published this year.

- Strength training improved leg strength but had no effect on cycling performance in 21 endurance-trained cyclists.
- Confirming previous knowledge, a study this year found that strength training results in an increase in the size, but not number, of muscle cells, and that cell-type populations remain the same. Most of the increase in size is in type IIB muscle cells (a type of fast-twitch fiber). The increase is about twice as much as in type I (slow-twitch) or IIA fibers.
- Another study found that strength training resulted in an increase in cross-sectional fiber areas—in this case about 25%. Of note, mitochondria (the energy factories of the cell) decreased by 13%. The important implication is that such training may increase strength, but may also reduce aerobic metabolism (and therefore aerobic fitness) in muscle cells.
- A so-called bilateral deficit has been appreciated for some time. This refers to the fact that power output of both legs separately is greater than that of both legs together. This may also have importance in the training technique of isolated leg training.
- Strength training just one leg also resulted in about one-third as much improved strength in the non-trained leg. The implications of this are important for those who injure a leg. Continuing to train by riding one-leg on a

trainer, for example, may help prevent atrophy of a casted leg.

- A strength training study this year confirmed what strength and conditioning coaches have known for a long time. Once strength trained, gains with reintroduced strength training after inactivity and atrophy are larger and faster than if training had not previously occurred.
- Muscle strength in cyclists was not strongly related to aerobic or anaerobic power.
- A lack of muscle oxygen can be a limiting factor in performance, and may have lab study importance since it can be measured non-invasively (without the need for blood testing) by near infrared spectroscopy.
- One set of weight training was as effective as three sets in strengthening the upper bodies of college-age males.
- One day per week strength training was 60% as effective in increasing strength as three days per week.
- Eccentric exercise was not more effective than concentric exercise in improving hamstring strength.
- Ballistic resistance training and/or plyometrics helped rowers' performance and running economy

Medicine

Traveling to a hot place and wondering about heat effects? A review of Boston Marathon runners found that the percentage of non-finishers rose from 20 to 30, that those who needed intravenous fluids doubled, and that ER visits more than quadrupled at the hottest marathons compared with the coolest ones.

A study of mountain bikers found that about 85% of injuries occurred riding downhill, and that falling forward (which occurred three times more often than falling to the side) was associated with more serious injury, especially injuries to the head.

Arterial narrowing, whether due to within the artery narrowing or external compression from muscle, is being recognized as a cause of limiting performance in elite athletes.

Cycling foot strains and ligamentous rupture are being recognized as causes of leg and foot pain, especially in mountain bikers.

Penile blood flow has been shown to be reduced in male cyclists. Genital numbness is common in both male and female cyclists. Whether this translates into an increased incidence of orgasmic dysfunction is still uncertain, but a modest increase appears likely.

Altitude Training and Competition— Manipulation of Oxygen Content of Air

For a complete review of this subject see my review in the Sport Science Webjournal, July 1998 issue, in the training and technology section. The web site is: www.sportsci.org.

At altitude, the reduced oxygen content of air or hypoxia, results in a decrease in VO_2 max, cardiac output, maximum heart rate, stroke volume, and power. They are all increased with supplemental or hyperbaric oxygen. Training under either of these opposing conditions may stimulate different body systems to adapt and perhaps result in improved performance.

Living-high training-low currently appears to be the best overall strategy. Gains in VO_2 max may be maximal one to three weeks after such an exposure.

High-low exposure resulted in lower oxygen use (greater economy) for a given power output in cycle-tested triathletes.

Hyperbaric oxygen did not help repair exercise-induced muscle injury.

Enriched-oxygen training didn't help moderately-trained cyclists living at sea-level.

Hyperbaric or other oxygen exposure prior to testing or competition probably doesn't help unless exposure is immediately (within a few seconds) prior to the event. Despite the common use of oxygen by football players between plays, this almost certainly has no physiologic value.

There appears to be some advantage to occasional periodized training in hypoxia, as two studies this year showed.

Acetazolamide (Diamox) is effective in reducing the symptoms of altitude sickness, but worsens performance.

Climbers eat less at altitude. Those traveling to altitude may need to pay attention to

carbohydrate intake and maintaining glycogen stores.

Delayed Onset Muscle Soreness (DOMS)

Researchers spend a lot of time investigating this problem because sore muscles—sore especially from eccentric exercise (muscle fibers lengthening while under tension)—prevent high-level performance in athletes

Studies this year showed that icing and heat may help.

DOMS does not inhibit the physiologic responses to sub-threshold work, but does increase perceived effort.

Magnets had no effect.

Stretching may help performance, but didn't change pain.

Perceived pain may have been less in a small study for a massage-treated group, but this group, by chance, had only a quarter of the pain as the placebo group, even before exercise began. Massage had no effect on blood markers of muscle damage.

Summary: Over the past few years studies have been inconclusive about the usefulness of almost everything for DOMS. They have shown that anti-inflammatory medicines, massage, stretching, ice, or heat may or may not help.

Prevention is key: When beginning new activities, ease into them. Don't start weight training, plyometrics, hill climbing, hard time trialing, intervals, or sprinting without base and transitional training. Allow the body time to adapt.

Psychology

Music did not change perceived exertion in a couple of studies this year.

Conclusions

As I usually find, there's a whole lot of interesting science out there, but only a limited amount of information that will prove helpful to improving performance. Knowledge is modestly incremental. There really isn't much revolutionary or new stuff that's going to make you a better rider. Training is still the key.