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The true method of knowledge is experiment.
William Blake, 1788

What's New?

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 rely on coaches, some of whom receive kickbacks if you buy on their recommendation? 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.

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 method is better than opinion or guessing, but it's not foolproof. Good sport science studies are hard to come by. Worse, 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.

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 is 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. Androstenediol, androstenedione, bee pollen, chromium, medium chain triglycerides, nasal dilators, and royal jelly are now out of favor.

An interested party pays for some studies. Peanuts were reported to help ballet dancers' performance (presumably by increasing 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.

Worse, imagine a company that pays for ten studies from ten 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. Recently 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?

A problem with sport science, unlike general medicine, is that studies tend to use small groups—fewer than 20 subjects. Small groups require relatively large differences to find statistical significance.

Studies often initially appear as abstracts. These present preliminary data, are often incomplete, are less subject to peer or other review, may be withdrawn, and are often cited in promotions by sponsoring commercial companies.

Keep in mind that it's 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 for the past eight years. This year's introduction and summary are the same as last year's. Again, I've culled over 2,000 abstracts, reports and papers during the last year. Some other-than-bicycling sports science may be relevant to bicycling and is included in this review.

Here's my synopsis and occasional spin on some of the published information on bicycle-related medicine and science that came out in 2002.

Each new paragraph generally represents a different study.

Nutrition

General

North American and European athletes tend to have relatively few nutritional deficiencies compared with Third World athletes who often have major nutritional intake deficiencies. In athletes without nutritional deficiencies, nutritional supplements do not exhibit an ergogenic effect.

Most studies find that general sports nutritional knowledge is suboptimal in all athletes. And although coaches often know and teach the correct information, they don't always practice what they preach.

Supporting this consensus, findings of good nutritional intake and poor nutritional knowledge were again reported this year in American field-hockey players.

Most endurance aerobic athletes eat more than their sedentary counterparts. Increased vitamin and mineral needs are generally met by this increased caloric intake. However, carbohdyrate needs are often suboptimal.

Many athletes try to restrict total caloric intake in order to lose weight or stay thin. Calorie-deficient women athletes are at risk for the female athletic triad (disordered eating, missed periods, decreased bone density).

Calories

General nutrient mix: It is commonly accepted, perhaps erroneously, that most aerobic endurance athletes should consume a diet relatively high in carbohydrates—65% to 70% of total caloric intake.

Many find this approach simplistic, and say it is more important to ingest enough carb calories to replace those lost through exercise. This often amounts to the same thing, but reflects an approach to the reasoning underlying the simplification. For example, it's not that an athlete consuming 3,000 calories per day needs 65% of calories from carbohydrates; it's that 7-10 grams/kilogram/day (2,000 carb calories for a 132-pound athlete) are needed to replace those lost during exercise.

This reasoning is also based on the premise that high-intensity exercise uses more carbs than fats, so maintaining high carb levels is crucial to high-level training and performance.

Carb ingestion before and during exercise helped soccer players sprint faster and play more skillfully during a 90-minute test.

A carb-electrolyte supplement improved 120-minute cycling performance in the heat.

Most cycling studies have shown that beverages containing carbohydrates enhance endurance performance. This was not the case in a running study this year.

A carb gel improved 5-km running time trial times compared with water or no treatment. Pre-exercise carbohydrates may result in higher or lower blood sugar levels during exercise, depending upon the exact timing of the sugar load. However differences disappear within 10 minutes of beginning exercise and had no effect on performance.

Other sugars such as galactose or trehose may result in lesser fluctuations. But these reduced fluctuations did not affect performance in another study.

Are athletes sensitive to their blood sugar levels? Perception of energy level during short-term moderately intense exercise was independent of blood glucose level.

Different exercise intensities did not change the glycemic response to pre-exercise feedings.

Pre-exercise carbohydrates in various amounts (25, 75, or 200 grams) did not affect 20-minute submaximal exercise and subsequent time trial (approximately 700 kJ) performance.

Milk consumed after strength training resulted in greater serum amino acid availability than a carbohdyrate beverage. There were no differences in strength gains.

Another study confirmed the increased serum availability of amino acids following protein ingestion; there were no changes in muscle protein translation.

A relatively high protein diet increased the amount of amino acids in blood in a study sponsored by the National Cattlemen's Beef Association. (Whether this translates into athletic benefit, as described for example above, is another matter entirely.)

Maximum fat oxidation rates occurred at 63% of VO2 max.

During endurance training, increasing the percentage of calories derived from fat to approximately 50% of total calories did not change adiposity, blood lipids, or other variables measured in a group of triathletes. (Total calories remained constant.)

An amino acid mixture consumed between two runs appeared to improve recovery, but the solution also contained carbohydrates and electrolytes. Although treatment and placebo groups consumed beverages before and during the runs, the placebo group was not reported as having received any solution during the recovery period between runs.

Pre-event feeding with medium-chain triglycerides did not influence high-intensity running performance.

Decreased blood sugar associated with prolonged, intense exercise is associated with decreased brain function—which is postulated to decrease performance and compromise safety.

Marathoners drinking carbohydrate beverages during their event were able to run faster with no perceived increase in exertion level.

Do high-carbohdyrate diets result in a relative “dependence” upon carbohydrates for energy production during exercise? The jury is not only out; it has barely started its deliberations. A study of carbohydrate recovery feedings found that a single bolus of carbs post exercise resulted in less carb use in subsequent exercise than splitting the carb dose into several recovery feedings. However, the subsequent exercise performance was the same.

Hydration

It is generally recommended that athletes consume enough fluids to replace sweat and urine losses during training and events. Since not all that is drunk is retained (about 60% is eliminated by the kidneys as urine), some advocate rehdyrating with 150% of lost fluids. Few athletes do. Many coaches and authors advise that even slight dehydration worsens performance.

Nine moderately-fit males performed a dehydrating exercise of 100 minutes in a vinyl sweatsuit. A 3.46% average reduction in body weight was not associated with decreased muscular strength or endurance compared with a rehydration protocol that resulted in 1.29% average reduction in body weight.

A solution containing sodium 75 mEq/L enhances fluid retention more than a solution containing 20 mEq/L.

Cycling in a hot environment for an hour? Drinking 1,000 ml of cool water immediately before cycling or splitting the fluids into four 250 ml aliquots at 0, 15, 30, and 45 minutes during the hour resulted in no significant thermoregulatory or performance differences.

A study comparing rehydration with water, sports drink (458 mg/L sodium, 6% carbohdyrate), and “Jamaica drink” (hibiscus sabdarifa, 4mg/L sodium, 5.2% carbohdyrate) found no significant differences in urine production. [This is contrary to the current belief that sodium helps rehydration in part by reducing urine production.]

Weight loss during exercise is related to fluid losses during exercise.

Predicting fluid loss before exercising based on initial body weight, exercise type, exercise intensity, ambient temperature, and percent relative humidity accounted for only about half of the variability of observed loss in recreational exercisers.

Superoxygenated water had no effect on exercise performance or recovery from exercise.

Glycerol resulted in hyperhydration and improved post-exercise rehydration. [I sometimes advocate an inexpensive alternative: salt.]

Vitamins and Minerals

A study this year suggested that vitamin C and vitamin E may help lung function return to normal in exercise-induced asthma.

Excess vitamin A intake may be associated with hip fractures. Weight-controlled athletes are often voluntarily calorically deficient (starved).

Post-exercise electrolyte replacement offered no rehydration advantage over plain water or electrolyte-carbohydrate beverage following 2% dehydration, the result of 75 minutes of cycling in an environmental chamber.

One study showed that 89% of marathon runners had lower blood sodium levels after their marathon than before. Those most prone to hyponatremia lost less weight and drank more. Ten of 45 subjects were clinically hyponatremic.

In Hawaii Ironman subjects, dehydration was 20 times more common than overhydration. Although overhydration may exacerbate hyponatremia, most hyponatremic athletes are de hydrated or appropriately hydrated.

Another study showed that hyponatremic marathon runners were more likely to be relatively hydrated than non hyponatremic counterparts. [Most marathon runners are dehydrated. Hyponatremic ones are generally relatively less dehydrated.] The symptoms of hyponatremia overlap with other exercise-induced states such as fatigue and dehydration. The only symptom more associated with hyponatremia than other conditions was vomiting.

Sweat sodium losses between 800 and 9900 milligrams were recorded in 13 NFL players during approximately 2-hour training practices.

Seven of 16 (44%) Iditasport human-powered ultra-marathon athletes had hyponatremia. These competitors drank more and consumed less sodium per hour than their normonatremic counterparts.

A multivitamin-multimineral supplement had no effect on endurance exercise-induced glutathione alternations (a marker for oxidative damage) in males or females.

Vitamin E supplementation did not affect recovery from multiple bouts of strength training.

A sports drink with added B vitamins had no effect on fluid uptake, substrate oxidation, or performance.

Mixed Nutrition

Male runners with increased iron stores don't use fats differently than those with low iron stores.

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 look at these substances.

Supplements are used by over 90% of athletes in some sports. Intakes are higher in men than in women. In high school and college, progressively more athletes use supplements as academic class (freshman through senior) advances. The most popular supplements are vitamins and minerals, creatine, and protein powders.

Many studies of athletes have shown that they have important deficiencies in knowledge about supplements. In the case of vitamins and minerals, intakes over 10 times the US Recommended Daily Allowances (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 US Food and Drug Administration issued warnings over the last few years about a number of supplements, marketed as sleep aids, aphrodisiacs, and muscle builders that have caused at lease 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 was 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.

A study a few years ago found that in one high school about 20% of male and 1% of female athletes used performance enhancing substances. When asked whether they would take such substances if they would guarantee a college scholarship but take 20 years off of their lives, 6% said "yes."

A sample of competitive bodybuilders found that urine and blood supplement levels were so high as to place the group at high risk for specific nutrient toxicities.

Acetazolamide, used to help prevent acute mountain sickness, was shown to impair performance when taken at sea level.

Anabolic steroids use was associated with adverse lipid effects. The effects disappeared when use stopped. The long-term effects are uncertain.

The anabolic steroid nandrolone may increase strength by increasing muscle mass, but resistance training is required to increase muscle quality (strength per unit of muscle).

Androstenedione raised serum testosterone levels, as well as estrogen levels, in a group of elderly men.

Steroid induced strength gains were lost after 12 weeks without the drug although strength training was maintained.

Arginine in a dose of 5 grams increases growth hormone levels.

Caffeine has been shown in many studies to improve some measures of athletic performance. Mechanisms of action are not completely known. In one study this year, average motor firing rate was not improved and therefore not the mechanism.

Caffeine and ephedrine supplementation significantly raised heart rate, blood pressure, and resting energy expenditure.

Caffeine did not improve 5-km time trial performance after 4 hours of steady riding at approximately 55% of VO2 max.

Caffeine, but not green tea nor ephedrine, increased resting metabolic rate in one study. Contrasting this, in another study, neither caffeine nor Xenadrine RDA-1 increased metabolic rate more than food intake.

Calcium pyruvate did not improve performance after 3 weeks of supplementation in division I athletes.

L-Carnitine before a 60-minute cycle test tended to increase carbohdyrate and not fat oxidation.

Chromium was very popular a decade or so ago. It has been less popular in the last few years; most studies have not shown it to be helpful. One study this year found that chromium improved some measures of cycling performance.

Cordyceps sinensis supplementation did not improve endurance performance in competitive male cyclists.

Creatine is one of the most popular performance-enhancing supplements. It was the most common ergogenic studied last year.

- Quadriceps contraction was not altered by creatine use.
- Swimmers did not improve performance or muscle mass.
- Creatine was suggested to alter electrolytes and responses to exercise in the heat, possibly contributing to swelling and muscle cramps.
- Creatine loading improved anaerobic cycling and sprint running in a group of Japanese athletes. Creatine was not related to injury or cramping in baseball or in football in another two studies. Creatine did not adversely affect heat tolerance in a study of women athletes.
- It did not improve anaerobic performance in a study of women performing Wingates.
- Creatine did not improve anaerobic work performance in a group of women tested on a cycle ergometer.
- A preliminary study suggested that adding magnesium to creatine may increase its uptake by muscle.
- Creatine improved muscle mass in men, not women; and bench press, not leg press strength.

Ginseng is claimed to enhance recovery through improved lactate clearance. A study this year failed to demonstrate this effect. Another ginseng study failed to find an effect on physical performance or heart rate recovery following exhaustive cycling.

Ma huang, a Chinese herb, is sometimes referred to as natural ephedrine. The herb contains a number of other alkaloids and metabolism is similar, but not identical to pure ephedrine.

Magnesium-creatine compounds of different types differentially affected fluid shifts and peak torque

Nonsteroidal anti-inflammatory drugs (NSAIDs) are used by many athletes to treat musculoskeletal injuries or prevent muscle soreness. How many? In an anonymous survey of 444 athletes, including 106 professional athletes, 88.5% had used NSAIDs in the previous year.

Salbutamol did not increase erythropoietin levels or red cell production.

Tyrosine, a dopamine precursor, added to carbohydrate ingestion did not improve cycling performance.

Magnets did not decrease pain nor did they improve several measures of performance..

Some have suggested that increasing the amount of oxygen available to tissues through hyperbaric chambers or tents may promote recovery or treat soft tissue injuries. Such treatment did not improve the recovery from exercise-induced muscle injury in a study this year.

Although massage is used to promote recovery, metabolism and oxygen use goes up during massage when compared to rest.

Equipment

An ice vest worn during normal active warm-up by track athletes (5K runners) did not improve running performance in moderate heat.

Wearing a cap during prolonged, moderate intensity running in a warm environment did not significantly alter thermal balance, thermal sensation, or physiological stress. The authors concluded that such practice should not compromise endurance performance or increase the incidence of thermal injury.

Heart-rate monitors from five different companies were accurate in measuring resting and exercise heart rate to within 1 bpm.

Forefoot midsole support did not improve running performance.

A study of the Hypoxico Altitude Tent showed that compared with levels measured in the air soon after entering the tent, carbon dioxide levels rose in the tent and blood oxygen saturation continued to fall over several hours.

Recumbent cycling was shown to use muscles differently than standard cycling, and to result in lower peak forces and reduced ineffective forces (for example, sideways pedal forces) at the same wattage.

Insoles did not alter muscular activity in healthy runners. [They are presumably even less likely to do so in cyclists.]

Optimizing time trial bike position balances the reduced power of the aerodynamic position with the improved aerodynamics. Steeper seat tube angles result in a more forward position and keep the athlete's preferred hip angle. They thus minimize the loss of power while improving aerodynamics.

The *Strength Cycle* (essentially a concurrent single leg cycle machine) did not provide strength or aerobic benefits over standard stationary trainer.

The Tanita bioimpedance estimate of relative body fatness was accurate to only 18% whereas the Omron bioimpedance machine was accurate to 3.5% in a study funded by Omron.

Physiology & Medicine

Physiology—Aging

Muscle quality, defined as force or torque/unit muscle mass, declines after age 65 and is more apparent in women according to one study. Another study came to a different conclusion. It showed that older adults have less muscle mass but mass of the same quality.

Physiology—Blood

Athletes were found to have lower hematocrits during the racing season, by a few percentage points. An increase in blood volume is associated with exercise. The relative contributions of the central nervous system, aldosterone, and urodilatin are uncertain. Reduced oxygen content of blood is accepted as common in aerobic endurance athletes.

Physiology—Blood Vessels

Entrapment of blood vessels by muscle or compartment spaces continues to be increasingly recognized as a source of leg pain in athletes.

Vascular endothelial growth factor, a cytokine that increases vascular permeability and induces angiogenesis, was found to increase in some, but not all athletes, following vigorous exercise.

Physiology—Bone

There is increasing evidence that endurance cycling is associated with bone loss. This may be as much a problem for men as it is for women.

One-and-one-half years of strength training improved spine bone density in older men and women. Hip density improvement occurred only in the men.

Cycling a century was associated with a stress hip fracture in a case report this year.

Physiology—Heart

Higher VO2 max levels are associated with an increase in heart rate variability (beat to beat variation). Training increases stroke volume, the extraction of oxygen from the blood by muscle, and max HR. In established athletes, the differences in VO2 max did not relate to stroke volume.

A sharp increase in aerobic training over 5 days was also associated with an increase in heart rate variability.

Physiology—Hormones

Does estrogen increase bone density due to an increase in muscle strength that preceded the bone changes? This hypothesis was not shown to be true in a study this year.

A single bout of exercise increases human growth hormone. The human growth hormone response to the second exercise bout is blunted. The mechanism is unclear. Acute resistance exercise increases serum testosterone levels for up to 15 minutes.

Physiology—Hypoxia/Altitude

Exercising in low oxygen was associated with increased deoxygenation of blood, not increased blood flow.

Some athletes desaturate more than others.

Higher heart rates at altitude result in part from decreased vagal activity.

The respiratory system showed progressive adaptations to repeated altitude exposure; the circulatory system did not.

Sweat rates may be reduced at altitude. This was not found to be the case in a pilocarpine-induced sweat study.

Ginkoa biloba was not more effective than placebo in preventing acute mountain sickness. Acetazolamide is the accepted pharmacologic agent for this purpose.

Nifedipine did not prevent pulmonary edema and it impaired performance.

Physiology—Immunology

Although exercise is associated with oxidative damage and immune system changes, the benefits of antioxidants and polyphenols is not established despite lay-press and advertising copy that suggests otherwise.

Vitamin C had no effect on the usual salivary IgA changes that occur during marathon running.

Another study also found vitamin C did not change blood immunity markers.

Some components of the immune system were shown to respond differently to carbohydrate ingestion during exercise in boys compared to adult men.

Physiology—Lung

Respiratory muscles do not fatigue in anaerobic work performed by aerobically trained female cyclists. [One interpretation: Commercially-available devices that improve respiratory muscle function, such as the PowerLung ® are not likely to benefit experienced cyclists.] Exercise-induced bronchospasm or asthma is not always easy to diagnose. Allergens and cold-air have been provocative factors.

Methacholine is used as an agent to provoke EIB. A study this year showed that it has a low sensitivity to identify elite athletes with the condition diagnosed by other methods.

Peak-flow measurements in cold air were found to be useful in diagnosing EIB.

Physiology—Muscle

Decreased muscle oxygen saturation has been postulated as a reason or marker for lactate accumulation above certain exercise intensities. This was found to be the case in one study and not the case in another study performed by the same research group this year. Exercise-related muscle damage in a triathlon race was not related to lipid peroxidation (free radicals). Mechanical factors were a postulated explanation. Muscle mass was directly related to power during fast and eccentric contractions in old adults.

Percent fast-twitch fibers were related to blood lactate concentrations.

Physiology—Neurology

A 70-mile-per-day 7-day road cycling tour was associated with decreased conduction of a deep motor branch of the ulnar nerve. Sensory changes and pain were not reported. Exercise in a sleep deprived state briefly reversed sleepiness and attenuated sleep-deprivation mood disturbances.

Physiology—Respiratory Tract

Cultures for many infectious agents were negative in runners who had post ultra marathon respiratory symptoms.

Physiology—Women

Exercise did not significantly ameliorate the symptoms of premenstrual syndrome in a study of 151 women.

Exercise for 40 minutes at moderately heavy intensity appeared safe during pregnancy at 34 to 38 weeks' (8 to 9 months) gestation. Pulmonary blood volume was lower during the early follicular phase of the menstrual cycle, which may influence lung diffusion capacity. There was no change in expiratory flow rates.

Estrogen alone, but not estrogen and progesterone, lowered the rate of glucose oxidation.

Anaerobic performance was best in the low estrogen-progesterone part of the menstrual cycle.

A study found that 57% of elite women ice hockey players aged 15 to 20 years self-reported irregular menstrual cycle length.

Percent body fat was less in women during the luteal phase of the menstrual cycle than in the follicular phase.

Testing

Every year sports scientists and physiologists report on a variety of testing methods that attempt to define and document easily-performed, reliable and valid methods of predicting performance. Many studies reported here will be of more interest to coaches than athletes.

Vertical jump was related to peak anaerobic power cycle ergometry in a group of elderly women.

A number of equations exist to estimate VO2 during submaximal leg ergometry. The ACSM equation is apparently more accurate than the old formula in both men and women.

Ten-minute protocols worked better than 30-minute protocols in identifying VO2 max plateaus.

USOC protocols for VO2 max testing often pair submax testing earlier in a testing session, with a 20- to 30-minute rest between tests. Some athletes so tested have lower VO2 max results than they do with a continuous test with no rest period.

Near-infrared spectroscopy determination of muscle saturation is being increasingly used to non-invasively determine exercise training intensity.

The energy cost of recumbent cycling can be predicted from the ACSM formula for upright cycling.

Wingate testing has been a standard method of assessing anaerobic power since 1989. Allometric scaling based on body weight is useful. Standing during anaerobic Wingate testing may enhance performance.

Increasing movement velocity allows more work to be done in resistance exercises such as squat and bench press.

Despite instructions to work "all-out," well-trained cyclists practice anaerobic pacing and tend to keep work levels relatively constant after an initial power-up phase. They keep similar anaerobic energy reserves for the last 200 meters in 500, 1000, 1500 and 3000 events.

Power produced at the ankle, knee and hip joints during cycling is approximately 20% to 33%, 45% to 70%, and 35% to 50% of total power delivered to the cranks. Power at 140 rpm was higher than at 60 or 190 rpm. The relative contributions remain constant over a wide variety of power outputs until high cadence (190 rpm), when the proportion produced at the hip increases and that at the ankle decreases.

Exercise-induced increase in growth hormone may be lower where GH aggregates are not accounted for in the testing method.

Predicting sweat loss by a variety of methods in a 30 km run was fairly accurate in warm, but not cool environments.

Training/Racing

Training/Racing—Cadence

Time trial performance of elite athletes in a lab over 8 km at a freely chosen cadence (92 rpm) was better than at a prescribed high cadence (101 rpm). Performance at a prescribed low cadence (83 rpm) was best.

Competitive athletes instructed to climb a 6 km hill as fast as possible at low cadence (55 rpm) or at a high cadence (83 rpm) had the same time.

The amount of oxygen used at 50 watts is higher at a cadence of 80 rpm than at 40 rpm.

Power output was higher during all-out five-second sprints at 120 rpm than at 60 rpm.

Triathletes pedaling at either 80 rpm or 100 rpm showed similar run mechanics after their cycling stage.

Training/Racing—Economy

Economy is the oxygen consumption for a given workload. Improving cycling economy is one method of improving performance. How much gain can be achieved? Elite male runners were found to use 6% less oxygen for a given workload than non-elite male runners.

Optimal stride rate for minimizing VO2 was found to be 86 per minute.

Training/Racing—Heart Rate Monitoring

Heart rate prediction equations generally underestimate heart rate max values for athletes. In older women, they were found to overestimate them. [Regardless of prediction models, individual variation is great and population values are useless for the individual.]

Training/Racing—Heat

Those who raced at US Masters Nationals at Bakersfield in 2002 faced temperatures around 115° F. Many wondered if cycling events are ever cancelled because of the heat, or if USCF guidelines exist to help promoters and officials make decisions at such events. How many chose not to compete? How many wished the promoter or officials to modify race distances?

In a report titled: "Senseless deaths: The impact of climate variability on heat-related mortality among athletes," the authors note that from 1985 to 1994 there were six reported heat-related deaths in football in the US. From 1995 to 2001 there were 19 deaths. Guidelines about training and competition do exist in football. The report called for greater responsibility in enforcing guidelines for exercise in such events.

Training/Racing—Hypoxia/Altitude

Training low and resting high is an accepted strategy for improving performance at sea-level.

Decreased fractional inspired oxygen leads to a decreased saturation of oxygen in blood. Sleep exposure is sufficient to stimulate EPO long enough to induce red blood cell formation.

Some coaches have made the argument that a variety of training approaches is likely to be beneficial. Although altitude camps have historically been the most common, altitude tents and chambers, hyperoxic training (with supplemental oxygen via mask) or hypoxic training (with reduced oxygen via mask or in a hypoxic tent or chamber) might also be useful.

For a more complete synopsis of this subject see http://arniebakercycling.com/free_articles/fa_altitude_training_for_sea_level_competition.htm.

Altitude tents may not be innocuous. A study this year suggests that altitude exposure is associated with bone mineral loss.

Not all athletes respond to altitude tents. Iron deficiency is sometimes an issue. A genetic marker for responders has been proposed.

A 10-day altitude camp at about 8,000 feet increased hematocrits from 47.4% to 49.7%.

Hyperoxic training has been used for almost a decade and allows for elite cyclists to increase the power output of intervals. Research about hypoxic training is relatively scant. It was reported to be of benefit 20 years ago.

This year three weeks of hypoxic interval training did not improve performance more than normoxic training.

Five weeks of hypoxic training in a flume did not improve 100m or 400m swim performance compared with normoxic flume training.

Twelve days of a live high train low regimen improved 4-minute, but not 30-minute interval times in five women members of the Australian national team.

Native sea-level and altitude athletes were compared. Sea-level athletes had higher maximal heart rates, higher peak lactates, and removed lactate more quickly than their altitude counterparts.

Altitude exposure was associated with negative mood changes in some athletes.

Training at altitude was associated with an elevation of an enzyme marker of heart damage in a group of highly trained male athletes who trained 50 miles in normobaric hypoxia.

Training/Racing—Intervals

When allowed to train at their own chosen intensity, well-trained runners exercised to perceived exertion levels of 17 out of 20 regardless of interval durations of 1, 2, 4, or 6 minutes. The highest VO2 levels were recorded during 4-minute intervals.

Running four 70-second intervals with 51-second recoveries resulted in lower blood lactate levels than eight 140-second intervals with 120-second recoveries.

Twice-a-week sprint training of four 30-second intervals for four weeks did not improve recreational cyclists' performance over their regular training.

Training/Racing—Power

Several studies have looked at the power demands of cycling. During a six-day national stage race, power at VO2 max was 416 watts for men and 313 watts for women. Power at lactate threshold was 288 watts and 203 watts respectively.

College students did not increase absolute and relative peak power more than non anaerobic training controls.

At 90 rpm and power outputs of 250 and 350 watts, mountain bikers tend to be the smoothest, road riders intermediate, and track riders mashers.

Training/Racing—Psychology

Perceived exertion and heart rate response to exercise did not differ in light and dark conditions.

Mood typically worsens during periods of heavy training.

Aerobic cool-down following moderately intense exercise does not produce more desirable post-exercise perceptions of the exercise experience.

Training/Racing—Respiratory Muscle

Respiratory muscle exercises improved performance in male competitive runners.

Training/Racing—Recovery

Easy off-season running helped regain cardiovascular and metabolic fitness gains more than threshold work.

There are no consistent markers of overtraining. Fatigue, increased perceived exertion for submaximal and maximal workloads are indicators.

Training/Racing—Strategy

Less than 5% of the performance variance of the 2001 Tour de France occurred during the four flat stages, prologue and team time trial. Climbing performance accounted for the greatest time differences. Small riders who can time trial well generally climb well. (Not all small riders time trial well.) Large riders who climb well generally time trial well. (Not all large riders climb well.) Several mathematical modeling studies this year show why this is true.

Training/Racing—Strength

Resistance training improves muscle strength. It may or may not translate to improved performance in aerobic endurance exercises such as cycling, soccer, or running.

As has been shown in years past, two studies this year show that a single set provides almost as much or as much benefit as three sets of resistance training. One study showed *greater* gains with a single set.

Contradicting the above, a sixth set at 50% of 1 rep max immediately after five sets at 90% max increased gains.

Combining strength and aerobic training in one workout can improve both fitness elements and be more time efficient, as two studies showed this year.

Training/Racing—Videos

Bored with stationary training? Inter-active cycling videos increased training time, but not intensity.

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.

Eccentric exercise-induced DOMS was evaluated in men and in women by two pain measures. It was lower in females than in males by one measure of pain, but not by another.

The NSAID Vicoprofen was associated with a pain-reducing chemical (Peptide F) more than ibuprofen or placebo in a drug-company sponsored study.

Ice had no effect on reducing DOMS.

Protease enzymes reduced DOMS.

Glycogen depletion did not make DOMS more likely.

Summary: Over the past few years studies have been inconclusive about the usefulness of almost all treatments studied for reducing DOMS. They have shown that anti-inflammatory medicines, massage, stretching, ice, or heat may or may not help. The effectiveness of placebo for DOMS makes meaningful investigation more difficult.

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.

The Past 9 Years

This is the ninth annual review of the sports science literature I've performed. This year's summary conclusions are the same as last year's.

- Sport scientists understand a little about what they can measure, less about what they can't.
- High-carbohydrate diets in the few days before events may be helpful. The rest of the time, the need for high-carb diets is less certain.
- Consumption of up to 300 calories per hour during exercise improves performance.
- Glucose polymers (maltodextrins) can benefit performance.
- Almost all vitamin and mineral supplements have proved worthless for most athletes in industrialized countries.
- Increasing salt ingestion the day before and during multi-hour events in the heat may be helpful.
- Most athletes don't consume nearly enough fluids to replace their losses during events. Much of the time it doesn't affect performance.
- The vast majority of so-called performance-enhancing drugs don't.
- The live-high, train-low approach may confer modest benefits in athletic performance.
- Lightweight and aerodynamic bicycle equipment has improved time trial and other performance times.
- Despite decades of research, selecting optimal crank length and optimal cadence is more of an art than a science.
- Masters athletes are a lot fitter than textbooks predict.
- Compared with the marketing hype certainty of anti-oxidants, very little is known about exercise and immunity.
- We understand a lot about causing muscle soreness; we know little about treating it.
- Stretching before training and races may worsen performance.
- Athletes respond to training.
- Heart-rate monitors, lactate monitors, and power monitors don't improve fitness. It's the training they monitor that does.
- A variety of intervals, from 5 seconds to many minutes, provides significant benefits for aerobic endurance athletes.
- Recovery is as important as work.
- Most athletes are limited not so much by genetics as by inadequate training.

Final Words

Knowledge is modestly incremental.

Key points: Hydrate. Have carbohydrates before, during, and after exercise. Be cautious about supplements, ergogenics, new techniques, and fads. Work on pacing during time trial type events.

If you want to have good luck, train.