Cutting-Edge Cycling

Advanced training for advanced cyclists

unter Allen • Stephen S. Cheung, PhD

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Cutting-Edge Cycling 高级自行车运动（2013年定）

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For all the cyclists and racers who want to improve. — HHA

For Debbie, my tandem partner on and off the bike. — SSC

Preface

Look through the archives of your favorite cycling photographer or magazine. The feel and ambience of hard athletes performing a hard sport remains the same, but the overall look of the sport today is far different from years past. Except for the basic diamond shape of the frame, bicycles are almost completely unrecognizable from 20 or even 10 years ago—from clipless pedals, brake lever and electronic shifting, aerodynamic road bikes and time trial–specific bikes, oversized and integrated headsets and bottom brackets, eleven-cog cassettes, compact cranksets and bike geometries, ceramic bearings, and wind tunnels to pretty much carbon everything. The dizzying pace of technological improvements has been such that cycling has often been likened to Formula 1 racing on two wheels, and this focus on technology is one of the underlying fascinations of the sport for many people.

Although the techno-geek angle within cycling continues to advance by leaps and bounds, the basic awareness and application of the science of training and fitness is unfortunately lagging behind for many amateurs and even professional cyclists. True, many cyclists would never head out for a ride without their bike computers, heart rate monitors, or power monitors. But numbers are just random digits without any meaning unless cyclists have the knowledge and understanding of what the values mean and how to use that knowledge to their advantage. Many athletes are still stuck in variations of the "just ride more and harder" mentality of training. Meanwhile, despite the scientific advances in equipment, which result in the ascendance of designs that prove better, training itself continues to be rife with old-school ideas that seem to gain added cachet simply because they're old. These ideas include such chestnuts as riding long steady distances and avoiding intensity in the off-season, riding a fixed gear to improve pedaling technique on the road, and using the knee over the pedal spindle as the optimal seat setback position. Such ideas and beliefs may or may not have merit, but rather than examine the evidence, many coaches and athletes blindly accept them simply because they've been handed down through the generations.

This concept of an evidence-based approach to cycling science and training is the philosophy underlying this book. Our goal is to bring a science-first perspective to cycling by digging into the scientific basis behind concepts such as lactate threshold, periodization, bike positioning, pedaling technique and cadence, nutrition, and recovery. From there, we develop proven and practical strategies to enhance your performance on the bike. Our hope is that this book will be equally useful to athletes and coaches by creating a common knowledge set and improving communication between the two parties and ultimately the performance of both. Just as a public that is better educated about health can cause doctors to become better educated themselves and more accountable, informed athletes and coaches spur one another to greater heights. We hope to increase the awareness of and appreciation for cycling sport science among athletes of all levels. Throughout the book, we not only examine the science but also present it in ways that are accessible and practical regardless of your level or experience. Case studies of individual cyclists illustrate how various concepts come into play when the rubber hits the road.

Chapter 1 focuses on the fundamentals of cycling science. With scientific advances comes marketing geared toward exploiting science as a magic ingredient. Therefore, chapter 1 begins with a simple primer on what science can and cannot tell us and how we can separate the wheat from the chaff when hearing about the latest "scientifically proven" advice. From there, we explain in chapters 2 and 3 how the body responds during cycling and how to quantify training and performance. What does lactate threshold actually mean, is it important, and how can cyclists plan their training around it?

The next few chapters give you the basic scientific knowledge and tools needed to translate physiology so that you can optimize your fitness while avoiding pushing yourself to the point of overtraining. Interviews with professional cyclists in the popular press are rife with references to building form and peaking for goals, but rare is the examination of what "form" actually entails. Therefore, we examine the dual nature of training stress and recovery, and we explain how to optimize both components to maximize your physical capacities. Chapter 4 outlines the scientific foundations of periodizing training to build your fitness throughout a season and over the years. Chapter 5 gives you practical insight into tools and techniques for optimizing recovery from hard training, and it takes you over the edge of fitness into overtraining so that you can avoid taking the actual plunge yourself. Chapter 6 is unique in examining the critical art and science of pacing your effort throughout a race. How you pace yourself in expending your finite energy over various events, from criteriums to flat and hilly time trials, can make the difference between stepping up on the podium and falling far off the back.

The next few chapters examine the important details that go into perfecting the man–machine interface. No matter how fit you become and how much energy you have in the tank, it all goes for naught if you squander it by being uneconomical and spending that energy when you don't have to. Chapter 7 takes you through the current scientific knowledge about proper positioning on the bike and outlines how to blend the science and art of proper bike fit. Chapter 8 looks at optimizing the fundamental act of pedaling properly, from biomechanics through the ongoing debate about optimal cadence.

The final chapters of the book cover the cutting edge in hydration, ergogenic supplements, and adaptation to extreme environments. Because innovations are becoming increasingly accessible to both professional and recreational athletes, understanding the science and applicability of these emerging technologies is important. The classic saying in computer science is "Garbage in, garbage out." Similarly, taking in the wrong nutrients at the wrong time can wreak havoc on your performance capacity; thus, chapter 9 focuses on some of the latest findings in hydration and sports supplements both on and off the bike. Finally, chapter 10 examines the latest knowledge on maintaining performance in extreme environments from enhancing performance through hypoxic and respiratory training to optimizing exercise capacity in inclement conditions.

One argument sometimes heard against the encroachment of scientific training is that using objective data turns us into robots enslaved by our gadgets. Another claim is that greater emphasis on science takes away from the mystique and beauty of cycling. Who cares about science when we all know that we should just ride more and harder? True, a basic attraction of cycling is the meshing of man and machine that may occur when you are completely "in the zone" while carving switchbacks down a mountain pass or riding in a great rhythm while climbing. But in cycling, as in other fields, art and science can not only coexist but also magnify and enhance the enjoyment of the whole. A great artist cannot be great without an inherent understanding of the physics of light and perspective, and a scientist aware of the complex biology of plants cannot help but become even more fascinated by the beauty of a flower. Our respective careers as scientist and coach have sprung from this precise philosophy—that the more we know about how the body works, the more enjoyable the already amazing experience of cycling becomes. Besides, at the end of the day, cycling is about speed, and it is just plain more fun to ride faster!

Acknowledgments

Cycling has been a central theme in my life since my early years of BMX racing. The support of so many friends, family, teammates, and coaching clients have kept me focused on my quest for more knowledge, lighter bicycles, faster computers, and the latest in cycling training. I owe each of them a big thank you and pat on the back for their continued support and help. From my own racing and training experiences, I have learned so much, but coaching others has taught me more than I thought possible. Each of my clients deserves a thank you for the opportunity they afforded me to work with them. The advent of power meters brought about a brand new dimension to this amazing sport, and I owe a debt of gratitude for all those power meter manufacturers out there that brought about these amazing tools for our continued improvement. All of my partners at Peaksware have my lifelong appreciation and gratitude as well, and I continue to be amazed by their incredible abilities to make my ideas, thoughts, and dreams come to reality. Thanks to my coaches at the Peaks Coaching Group as well, as their questions keep me on my toes, force me to create new presentations and ways of teaching that inspire them and their clients.

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—Hunter Allen

Where would my life have wound up without two wheels under me? I did my first degree in oceanography, but my passion for cycling was what led to my switch to kinesiology, with hopes of becoming a cycling scientist and learning more about how my body works. So cycling has brought me some of the greatest moments and joys of my life—especially because it was through cycling that I met my wonderful wife Debbie. It has also been through cycling and science that I have met the most diverse and entertaining group of friends, including not only the numerous folks that I have shared the miles with, but also many of the fellow scientists that are interviewed in this book. Truly our sport is like no other in its freedom to take you on the journey of a lifetime.

My thanks go to Richard Pestes and the crew of PezCycling News. Being with Pez has given me the perfect outlet for combining my love for cycling along with my scientific background, fulfilling the dream I first started out with when I entered graduate school.

Finally, thanks to Graham Jones for hovering over my shoulder all these years!

—Stephen S. Cheung

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CHAPTER 1

Evaluating Cycling Science

Although the human body itself doesn't evolve on a yearly basis, scientific information about exercise physiology is increasing exponentially. This growth can be seen in the number of papers published each year and in the ever-increasing number of scientific journals devoted primarily to sport and exercise. The way that the body works is not fundamentally changing; rather, the body of knowledge about how it works is expanding.

A number of factors are fueling the growth of the field of sport science. First, health professionals and governments are recognizing that physical activity is a preventive medicine for many illnesses. Research funding is therefore becoming more readily available. Indirectly, the Olympics have played a role by highlighting and stimulating research into particular exercise topics. Examples include altitude training from Mexico City (1968), heat stress and cooling measures from Athens (2004), and pollution effects on exercise from Beijing (2008).

Second, new tools and techniques for quantifying activity, such as portable power and portable metabolic analyzers along with metabolic machines for obtaining real-time data on riders during training and races, have broadened the avenues of study in the field. In the lab, new techniques and advances in molecular and genetic analysis permit scientists to investigate questions that simply could not be asked a decade or two previously.

Changes in the professionalism of sport itself are also driving the development of sport science as a field of research and work. With the dominance of sport in popular culture comes an increasing call by sponsors, athletes, and the public for performance. In turn, this demand motivates teams to seek advantage in every available avenue (only legal ones, we hope!) for improving performance. One by-product is that athlete care and training support has been largely taken out of the hands of traditional team staff members, who are often former amateurs or professionals who have minimal scientific training. Instead, teams are now open to hiring sports medicine specialists and sport science professionals who have been trained in the field. University graduates can make a career out of working with teams and athletes, and they come into the field with an appreciation for new ideas and approaches. Probably the most publicized example is the work of Allen Lim, PhD, with Jonathan Vaughter's Slipstream program. Although not the first to introduce technology like ice vests and compression garments to pro cyclists, Lim and Slipstream popularized their use, and the team's success has spurred others to explore the same advantage.

Technological Breakthroughs

Probably the seminal event in the scientific evolution of cycling was the systematic approach used by Francesco Moser in his shattering of the world hour record in 1984. Along with pioneering the use of an aerodynamic time trial frame and disc wheels, Moser used the newly developed Conconi test to determine anaerobic threshold and trained with specific heart-rate-based methods based on such testing (Conconi et al. 1996). This approach was supplemented by the development and use of portable heart rate monitors to enable real-time monitoring of effort. Since that time, heart rate monitors have become ubiquitous for cyclists and multisport athletes of all levels. Unfortunately, without the knowledge to analyze and interpret the data, heart rate just becomes another meaningless number on a screen. Over the past decade, power monitors have become the new standard in training tools, and coaches such as Hunter and scientist Andy Coggan, PhD, have been pioneers in the systematic and detailed use of this tool to quantify training and maximize fitness. However, power is a random number unless the user knows how to interpret it.

But how much science and how much high-tech gadgetry do most people need to enjoy cycling? How do sport science improvements filter down to the everyday cyclist? Our view is that even the recreational age-group cyclist who simply likes to ride the occasional century or Gran Fondo event can enjoy keeping up with new ideas as they emerge, because doing so advances the sport and the cyclist's enjoyment of it. Yes, getting a new set of high-end carbon tubular wheels and getting faster that way is neat, but adopting a new and proven training idea is the physiological equivalent to those wheels, and it will get the cyclist faster in the end.

The influence of training and technological advances were nicely summarized in a study by Dr. Asker Jeukendrup (Jeukendrup and Martin 2001), who in addition to his cycling research has worked with the Rabobank professional cycling team. How much faith should we place in technology to enhance our performance, and where should we place our priorities and spend our money? Using a baseline cyclist of 70 kilograms racing a 40K time trial at either untrained (48 milliliters $\dot{V}O_2max$, 72:56 time), trained (66 milliliters, 58:35), or elite (80 milliliters, 52:02) fitness while riding on the handlebar hoods, Jeukendrup and Martin (2001) modeled and ranked in relative importance the effects of various interventions, both fitness and technological. A summary of some of the possible improvements is presented in table 1.1.

For a novice athlete, big improvements in a simulated 40K time trial (TT) can come from improvements in both training and aerodynamics. So although equipment changes and buying stuff will indeed get the cyclist "free speed," similarly large benefits come from enhancing physiological performance and bike fit, and that is where training and coaching based on sound evidence come into play.

As seen in table 1.2, scientific evidence can also guide us in our equipment choices. In the tradeoffs between aerodynamic versus lightweight equipment, the former is often seen to be a priority in flat races, whereas the quest for light equipment dominates when climbing. The modeling from Jeukendrup and Martin (2001) provides strong support for this view, but with an important caveat. Namely, at moderate grades, aerodynamics remains important, especially with higher fitness because of the higher speeds.

TABLE 1.1 Relative Benefits of Various Strategies for Improving Performance in a 40K Time Trial

	Training	Decreasing body weight by 3 kg	Hoods—drops	Hoods—aerodynamics	Hoods—optimized aerodynamics
Novice	–5:27	–0:25	–3:46	–6:49	–9:21
Trained	–1:45	–0:21	–3:06	–5:36	–7:42
Elite	–1:02	–0:19	–2:47	–4:59	–6:54

TABLE 1.2 Relative Importance of Bike Weight and Equipment Modifications During a 20K Climbing Time Trial

	DROPPING BIKE WEIGHT FROM 10 TO 7 KG			SWITCHING FROM AERODYNAMIC TO LIGHT WHEELS		
Grade of climb	3%	6%	12%	3%	6%	12%
Novice	–1:34	–3:38	–7:25	+0:10	–0:25	–1:12
Trained	–0:42	–1:52	–4:02	+0:20	–0:03	–0:35
Elite	–0:29	–1:15	–2:48	+0:21	+0:06	–0:22

Evidence Versus Dogma

Despite such advances in understanding how the body works and how to maximize its physical potential, changing the ideas held by individual riders remains difficult. Too often, new riders rely on advice that they hear from their riding partners or club members, who heard the same advice when they started. Such knowledge becomes ingrained in the culture of the sport, and persuading successful athletes to try something that is out of their normal routine can be challenging. After all, why fix it if it isn't broken? For every rider like Greg LeMond, who was always open to new training ideas and equipment and who popularized everything from sunglasses and aerobars to power-based training and peaking for particular events such as the Tour de France and Paris–Roubaix, there are countless riders who will stick with what they know and therefore trust. Old advice is not always bad, of course, but a better approach is to assess information rather than blindly accept it without analysis. It is time to take a hard look at what does and doesn't work in the world of training and fitness. But if we are going to dig into the underlying science to develop training ideas, first we need to have a clear understanding of both the strengths and the limitations of the scientific literature.

Here are some examples of ways in which scientific advances have improved cycling performance and the lessons that we can draw from them about the benefits of the scientific process. We examine these topics in detail in subsequent chapters:

- **Precooling.** Cooling garments were initially developed by NASA for use by astronauts during spacewalks, and the Australian rowing teams first popularized their use for precooling before races in the mid-1990s (Flouris and Cheung 2006). Did Team Slipstream win the 2008 Giro d'Italia team time trial (TTT) because they used cooling vests? Or did they win because of particular equipment choices, the specific training that they did as a group in the weeks prior, better fitness, or simple luck? Certainly, Slipstream's success that day has probably caused other teams to consider the use of cooling vests, but how can we tell for sure whether such interventions work? Rather than a blind "monkey see, monkey do" process of emulating what others did, the most notable characteristic of most scientific investigations is the use of a control group versus an experimental group. This aspect is the heart of the scientific method. A control group refers to a group that receives the same testing but without the experimental intervention. Such a design permits the isolation of that particular intervention and the removal of confounding factors. For example, a study on precooling should have a trial in which a subject is precooled before testing and another trial in which the subject rests for a similar length of time but receives no precooling (Cheung and Robinson 2004). Without this control trial, determining whether precooling is effective is simply impossible. In chapter 10 we look closely at whether the evidence suggests that precooling results in improved performance across all types of exercise.

- **Altitude tents.** Altitude training was first stimulated by the Mexico 1968 Olympics. The development of artificial altitude facilities in the late 1990s and early 2000s helped to reduce the need for high-altitude training camps. The emergence of such commercial technologies demonstrates the symbiosis between sport and science in that greater demand by athletes drives scientific inquiry because scientists need to keep up by developing scientifically validated and safe protocols for their use.
- **Fluid replacement and sports drinks.** Although athlete feedback is important, some information can only be gained through using laboratory techniques in a controlled setting. One example is the direct measuring of emptying rates from the stomach and intestines of various fluids during exercise. New advances in cellular analysis have also provided information on how the body's metabolic demands change with different exercise durations and different environments like heat and cold. Such laboratory-specific techniques have enabled the development of sports drinks calibrated for optimal nutrition during exercise. Some of the latest advice on hydration strategies is surveyed in chapter 9. The use of scientific data quickly accelerates the development of new products, because it provides concrete information that can then be complemented by athlete testing.

Q&A With Ben Sporer: From the Lab to the Road and Back Again

Current position	Physiologist with Canadian Sport Centre Pacific.
Professional relationship and background with cycling	Physiologist and sport scientist with Canadian National Cycling and Triathlon Teams.
Personal background with cycling	Road and mountain bike—some recreational racing.
Favorite ride (either one you've done or always wanted to do)	Spruce Lake in British Columbia's Chilcotin region—beautiful alpine passes, epic downhills, and flowing single track.
Favorite cycling-related experience	Coffee rides and annual riding trip.

(continued)

Ben, you're a PhD who's worked a lot with top cyclists and triathletes in and out of the lab. Do ideas come from the athletes out on the road and trails, or do they come from the lab?

It's funny that you ask this because I was recently having a discussion on this exact matter with sport psychologist Dr. David Cox. Our outcome was that science drives practice while practice leads science. It really is a bit of both. Cyclists and coaches live and breathe the pursuit of performance every day and because of this are constantly on the lookout for strategies, techniques, and modifications to training that enhance performance. Some of these ideas may have originated in science, but many also come from personal experiences of the coach and athlete. As a scientist who works with athletes, you need to be a student of the sport. At the same time, athletes and coaches need to embrace the fact that science can provide innovative ideas and real solutions to the challenges of cycling. I believe it is a mutual respect for both that advances our understanding of the sport.

Then what's the biggest single thing that you've learned about how the body works from working with athletes?

The single biggest thing? There are many but I guess I'd have to say that the body truly works like a machine but that each machine is unique. Often in science, we take a reductionist approach and break down the parts of a complex system like the human body to determine how its various components function. Obviously, this has great benefits and has driven our understanding of how the human body operates immensely. But when working in elite sport, you need to take a holistic approach to understanding individual responses to different stressors in different situations. It's critical to have a good understanding of each individual's strengths, weaknesses, and responses in an integrated context that takes into account the many factors affecting performance—nutrition, psychology, environment, training history, level of competition, and so on.

With so much information out there in books, on the Internet, and from coaches, how do you advise athletes in terms of sorting out the wheat from the chaff? How do you help them to figure out the science?

This is a big challenge because there is an information overload, and it's a difficult task to make sense of it all. The most important thing is to help athletes understand whether or not there is a physiological basis for an idea or strategy. That said, there's not always scientific evidence for some of the things that athletes and coaches do, yet their actions are very effective in real-world situations. I try to get them to think critically to see whether there's a physiological basis for it and to think about where they're getting the information from.