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In 1986, Uli Schoberer, a German engineering student and cyclist, invented the mobile cycling power meter—the Schoberer Rad Messtechnik, or SRM. Up until that time most cyclists relied almost exclusively on perceived exertion to gauge intensity during a ride. A few riders in the 1980s were also using heart rate monitors—another new invention that was only about ten years old. But the problem with heart rate was its slow response during short accelerations, which are common in cycling, and being affected by variables such as weather, mental stress, and diet. By the 1990s the SRM was growing in use among professional cyclists. But as they were more expensive than most bikes at the time there were few in use outside of the pro peloton. It wasn’t until the early 2000s as prices came down that power meters were widely adopted by serious recreational riders in a wide range of cycling sports.

Up until the invention and widespread use of the power meter, cycling was perhaps the least scientific of all endurance sports. While swimmers and runners in the 1970s and 1980s were taking tiny blood samples at the pool or track to determine changes in lactate levels at various paces, serious cyclists were primarily focused on volume—miles, kilometers, and hours. Weekly saddle time was the gold standard for determining progress. Why not speed? Wind, hills, and drafting made miles or kilometers per hour practically useless on the road.

Then along came the SRM and things began to change, albeit slowly. Now there are several companies making bicycle power meters and the prices have come down considerably since the 1990s. Road cyclists, mountain bikers, triathletes, track racers, and other riders at all levels of performance have found them to be a great way to measure training progress. Cycling has gone from one of the least scientific endurance sports to arguably the most scientific because of the power meter. Non-cycling sports such as rowing, competitive sailing, running, and others now are starting to use power meters.

I finally got my hands on a power meter in 1995. It was a loaner from SRM. As a poor coach I couldn’t afford to buy one. Uli was very kind to let me use it for three months. At the time I was writing my first book—The Cyclist’s Training Bible—and wanted to include something on this new technology. I wrote one page in the book on what I had learned about training and racing with power. As far as I know this was the first-ever description of how to train with a power meter. There wasn’t much to say because I didn’t know much.
In 1998 I got my second power meter. It was a prototype from a new start-up company called PowerTap. Instead of being in the chainring spider as with the SRM, PowerTap's strain gauges were in the rear hub. The price was now much more manageable. I've been training and racing with power ever since.

By 1999 I was starting to understand quite a bit about how to use a power meter, or at least I thought so at the time. So that year I wrote a 32-page booklet called *Training with Power*. I would certainly not call it the definitive guide on how to train with power. It was just a small step in the right direction.

In 2006 Hunter Allen and Andy Coggan, PhD, released their first edition of *Training and Racing with a Power Meter*. From one page to a book—my how things had changed in only ten years. They introduced then what has become the most widely accepted methodology for using a power meter in cycling. From my oversimplified single page on the topic in the mid-1990s they had come up with a system that revolutionized training and set a standard for other sports to aim for. And the amazing thing is that they are still innovating and changing how the world of cycling trains and races.

What you have here in your hands is the most complete and advanced book on power-based training ever written. It’s amazing to think that so much about how we ride a bike and prepare to race could come from a single data point—what your wattage is right now as you ride. My single page on the topic in the mid-1990s went no further than that. Coggan and Allen—along with Stephen McGregor, PhD—have taken that jewel of data and turned it into a unique training method that continues to evolve while revolutionizing how we train. Other endurance sports are observing and adopting what is so thoroughly explained in the following pages. Coggan, Allen, and McGregor are changing the world of competitive training.

On a more personal level, your training and racing will also improve as you come to understand and adopt the methodologies they describe in the following pages. It won’t be easy. Change never is. But if, like most serious athletes, you are always seeking more effective ways to raise your level of performance, then this book, used along with your power meter, will provide the guidance and direction you need.

—Joe Friel

*Coach, Author, and Co-Founder of TrainingPeaks*
Introduction

Believe it or not, the first power meters, or ergometers, appeared in the late 1800s. These were essentially stationary bikes that allowed researchers to determine power, but they were not practical for everyday use and certainly not portable. Only in the last few decades have key technological advances made power meters portable, cheaper, and ultimately accessible to cyclists at all levels of the sport.

What was once a secret closely guarded by top coaches and a few select, elite athletes is now considered essential equipment. Power-meter data is a focal point in race coverage, so even cycling fans are increasingly familiar with the wattage output of standout riders and the analysis of their data. Social media platforms that allow riders to share the data from their rides and tout their power-to-weight ratio like a badge of honor can also be credited with bringing power to the masses.

Because power meters and the software that supports them have become far more accessible, both in price and in practice, there’s never been a better time to incorporate power into your training. We want to demystify the power meter so you can tap into cycling’s best technology and achieve peak performance in your training and racing.

HOW WE GOT OUR START

Andrew Coggan, PhD, an exercise physiologist, first began working with ergometers in the early 1980s in his exercise physiology lab. Creating testing protocols that used specific workloads (wattage), he learned how carbohydrates work in the body and how blood lactate levels affect an athlete’s performance. He eventually wrote numerous scientific papers relating to the subject. A talented cyclist himself, Andrew often took advantage of indoor ergometers to improve his own training and racing—with great success. With the introduction of a less-expensive mobile power meter in the mid-to-late 1990s, he began to collect even more data while racing and training outdoors. From what he had learned in the lab, he knew that this tool would benefit cyclists training in the “real world” by quantifying the demands of racing, by improving pacing, and even by tracking fitness changes. Soon, however, it became clear that this tool would provide many cyclists with more information than they could handle. Andrew set out to create a schema for training with a power meter and began teaching the coaches at USA Cycling how to use it. You’ll find a lot of this information in Training and
**Racing with a Power Meter.** For these educational efforts, in 2006 he received USA Cycling’s Sport Science Award and was among three finalists for the US Olympic Committee’s Doc Councilman Award.

Hunter Allen, a former professional cyclist, elite-level cycling coach, and the owner of the Peaks Coaching Group, began coaching endurance athletes in 1995. He worked with several athletes who were early adopters of power meters in the late 1990s. As their questions about training with power multiplied, he committed to exploring the technology further. In 2003, Hunter Allen, Andrew Coggan, and Kevin Williams developed TrainingPeaks WKO Software, a valuable program that helps athletes analyze workouts, compare race data, and track progress. Although he is no longer one of the owners of TrainingPeaks, Hunter is now known as one of the world’s experts in training and coaching with a power meter, having analyzed thousands of power-meter files and successfully coached hundreds of athletes using power meters. Hunter has traveled to over 20 countries and taught the principles of power training to over 5,000 coaches and athletes, along with authoring numerous articles on the subject. Hunter, as the technical coach to the USA BMX Olympic team in 2008, brought power-meter training to the BMX world and has coached multiple world and national champions as well as elite riders in the Olympics, Tour de France, and Ironman® world championships.

Stephen McGregor, PhD, also an early adopter of power-meter technology, is director of the Applied Physiology Laboratory and the Sport Performance Technology Laboratory at Eastern Michigan University. Since 2005, he has been a USA Cycling instructor responsible for teaching coaches about physiology, general training, and power training. Since 2013, he has served as co-lead instructor for the USA Cycling Level 1 Elite coaching certification. He is the co-author of *The Runner’s Edge* ebook, in which he developed the run Training Stress Score (rTSS) and normalized graded pace (NGP). Stephen also coaches for Peaks Coaching Group, guiding multiple athletes to national and world championships in road cycling as well as Olympians in various disciplines. In 2016 he was the recipient of an Order of Ikkos medal as the coach of an Olympic medalist in track cycling. His own experience, first as an elite cyclist and more recently as a masters-level athlete, helps him keep the science and data analysis grounded in the day-to-day concerns of training and racing. He tells athletes: “When it’s all said and done, the science doesn’t matter if it doesn’t help you go faster!”

**HOW YOU CAN GET STARTED**

For a cyclist who wants to reach a new threshold of achievement, a power meter is an invaluable tool. It can help you uncover hidden areas of weakness that never would have come to light through the use of a heart rate monitor or simple cyclometer. Capturing a second-by-second diary of your ride that you can later download and analyze, a power meter is a data goldmine.
Far from being just another gadget on your bike, the power meter can help you track your improvements over any period of time. Would you like to compare this week’s hill repeats to last week’s? How does your best 20-minute effort from this year compare to your best 20 minutes from two years ago? How has your average cadence changed over the past three years? With a power meter and a few clicks of the mouse, you will have the answers to these questions and so many more. What you learn could very well be the difference between a mediocre season and a successful one.

*Training and Racing with a Power Meter* will show you how to mine the data for better performance. Chapter 1 explains how using a power meter will impact your training. Chapter 2 delves into how the equipment works and how different software interprets the data. Chapter 3 will teach you how to find your functional threshold power and further individualize your training levels. Learn how to use a power meter to identify your strengths and weaknesses as a cyclist in Chapter 4. You’ll find some sample workouts in Chapter 5, all of which are based on wattage—time trials, hill climbs, interval training, and so on. These workouts target the goals of the power-based training levels.

Chapter 6 is where you will begin to interpret the data from your rides. Sample graphs illustrate the important concepts that you can explore using your power-meter software. Normalized Power, Intensity Factor, and Training Stress Score are explained in Chapter 7, allowing you to dive deeper into the data. Chapter 8 covers the numerous advances, new concepts, and tools developed since the previous edition was published, including concepts like functional reserve capacity and stamina. The real value of these concepts comes to light in Chapter 9 as we explore the process of using the data to create and time peak fitness.

Although the focus of this book is not on training, Chapter 10 presents four case studies on training with power. Each case study contains a fully developed training plan that you can use or adapt for your own training. You will see how the workout menu in the Appendix can be used in your own training, and you will get a better understanding of how to develop your Power Profile and build fatigue resistance specifically where you need it most.

Chapter 11 explains what the data will mean over a longer period of time. For example, you can use the power-meter data to track long-term changes or compare races from year to year. Again, we’ll give you concrete examples of how you can use your power-meter software to reach your goals.

Triathletes benefit tremendously from power meters and the insight they provide into effective pacing. Chapter 12 explains how to train properly for both long- and short-distance events and also includes some key racing advice.

Chapter 13 takes a closer look at how to use the power meter to reach your peak performance in racing. Chapter 14 discusses other cycling disciplines and how to effectively use a
power meter in cyclocross, track, and ultra-endurance events. Finally, the epilogue summarizes the important steps in putting it all together.

In the Appendix, you'll find more than 100 sample workouts sorted according to training level. These are just a starting point. After reading this book and figuring out your own Power Profile and Power Duration Curve, you'll undoubtedly want to build a few workouts of your own.

There is a lot of terminology and technical jargon in this book. If you are anything like us, you'll love it. For the moments when you can't keep the terminology straight, use the Abbreviations (pp. xv–xvi) or the Glossary (p. 351) to sort it out.

Again, this book is not a training manual—it will not explain the nuances of peaking or go into the details of exercise physiology. There are many great books that go over these concepts in depth. Our goal is to teach cyclists at every level of ability that training and racing with a power meter is not hard to do. You do not need a PhD in exercise physiology to understand what the data mean. Furthermore, you do not have to be an elite racer to benefit from the technology the power meter offers. If you are a cyclist with an interest in improving your performance, this book is for you, whether you have a power meter already or you are just considering purchasing one. Any athlete can benefit from being challenged to think critically about training and will come to a better understanding of the essential components that comprise peak performance.
About the Authors

**Hunter Allen** is considered a foremost authority on using power meters to excel in endurance sports. Over the course of his coaching career, he has analyzed thousands of power-meter files and consulted with companies to further the capabilities of power-meter software and products. Having taught USA Cycling power certification courses since 2005 and traveled to more than 20 countries, Hunter has equipped thousands of coaches and cyclists with the principles of training with power.

A USA Cycling Level I coach, founder of the Peaks Coaching Group (www.peakscoachinggroup.com), co-founder of TrainingPeaks Software, and a former professional cyclist with the Navigators team, Hunter has been coaching endurance athletes since 1995. His Peaks Coaching Group athletes have achieved more than 2,000 victories, numerous national and world championship titles, and Olympic medals. Hunter was also the BMX technical coach for the 2008 Beijing Olympics.

Hunter holds a B.A. in Economics from Randolph-Macon College. He resides in Bedford, Virginia, with his wife, Kate, and their children, Thomas, Jack, and Susannah.

**Andrew Coggan, PhD,** is an Associate Professor in Kinesiology and Cellular and Integrative Physiology at Indiana University–Purdue University Indianapolis. He has published numerous scientific articles on a diverse range of topics, including the physiological adaptations to endurance training and the effects of aging on muscle metabolism during exercise. Most recently, his research has focused upon the effects of dietary nitrate on muscle contractile function.

Formerly a national-caliber masters cyclist and time trial record holder, Andrew is also widely recognized as one of the leading experts on the use of power meters in training. Many of the concepts discussed in this book and featured in WKO4 and other desktop or online software are the result of Andrew's work with cyclists and coaches. As a result of his contributions, in 2006 he was honored by USA Cycling with their Sport Science Award and named a Finalist for the US Olympic Committee's Doc Councilman Award.

Andrew Coggan earned his PhD in exercise physiology from the University of Texas and an MS in human bioenergetics from Ball State University. He lives in Brownsburg, Indiana, with his wife, Angela (a former elite national champion track cyclist), and children, Madeleine and Gavin.
Stephen J. McGregor, PhD, is a pioneer in the development of training concepts and software designed to maximize the benefits of training with technology. Most notably, Stephen created the normalized graded pace (NGP) algorithm and the run training stress score (rTSS), specifically designed for running. He has also developed the Dynamic Training Load (DTL) system for quantifying training load in dynamic team sports.

Stephen is the director of the Applied Physiology Laboratory at Eastern Michigan University and has published and presented numerous research papers examining muscle injury, performance modeling, running physiology, and performance quantification using technology. He earned a doctorate in exercise physiology and has served on the science and education faculty for USA Cycling since 2005 where he presents Power and Elite Level 1 Coaching certification clinics.

A former intercollegiate soccer player, triathlete, and elite competitive cyclist, Stephen has coached endurance athletes for almost 25 years and serves as a coach/consultant to numerous international and Olympic-caliber cyclists and runners. In 2016 he was the recipient of the Order of Ikkos as the coach of an Olympic medalist in cycling.
YOUR POWER METER IS
THE ROAD MAP TO FASTER RIDING

From the amateur to pro ranks, cyclists and triathletes use power meters to gain speed and endurance. *Training & Racing with a Power Meter* unlocks the treasure trove of data at your fingertips to help you understand and redefine your performance on the bike.

Get the latest advances in power analysis from the world's leading experts:

- Optimize your training levels with a new, more individualized method
- More accurately target intervals based on your unique physiology
- Use the Power Duration Curve to reveal your functional reserve capacity, stamina, and time to exhaustion
- Improve efficiency by balancing power and technique throughout the pedal stroke with left/right power data

See how your Power Profile stacks up against the different types of cyclists—all-rounders, time trialists, climbers, sprinters, and pursuers. With hundreds of power charts from men and women of a wide range of ages and ability, you will discover exactly what kind of training you need to become a better cyclist.

After identifying your Power Profile, you will be able to develop a customized, power-based training plan that plays to your strengths. You can draw from case studies, detailed plans, and over 100 workouts designed to achieve a variety of goals—threshold improvement, peak performance, half-Ironman racing, and gran fondo riding. You will also find guidance on training with power to meet the specific demands of cyclocross, track, and ultra-endurance events.

*Training & Racing with a Power Meter* is packed with expertise and colorful visuals that will give you the skills you need to crack the code for converting power data into speed.

**HUNTER ALLEN** is an elite-level cycling coach, former professional cyclist, USA Cycling instructor, and owner of the Peaks Coaching Group. **ANDREW COGGAN, PhD.** is an exercise physiologist and a leading expert on power-meter data and application, responsible for developing many of the key metrics. **STEPHEN MCGREGOR, PhD.** is an exercise physiologist at Eastern Michigan University, USA Cycling instructor, and coach for Peaks Coaching Group.