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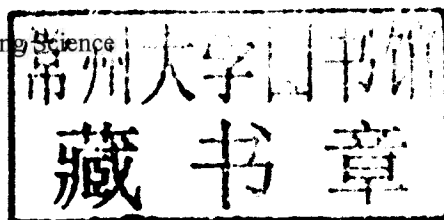
Owen Anderson, PhD

Running Science

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跑步训练

Running Science



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Prologue

The Quest for Knowledge in Running

The science of running is undergoing a revolution that has now entered its fifth decade. In the 1970s, exercise physiologists were sure that endurance running was an oxygen game, with oxygen limitation the key cause of fatigue during exercise and $\dot{V}O_{2\max}$ the main physiological variable to be examined.

From a scientific perspective, endurance runners were little more than hearts and leg muscles. The heart was the pump that sent oxygen to the waiting sinews in the lower appendages, and specialized structures in those muscle fibers called mitochondria permitted the muscles to use oxygen to provide the energy necessary for running. Once the limit in that system was reached, anaerobic energy took over, lactic acid built up in the muscles, and the hapless runner was done for the day. A competitor with a better oxygen-delivery and supply system won the race.

In that model, which had its origins in the 1920s at the Harvard Fatigue Laboratory in Cambridge, Massachusetts, where the work of Nobel Prize-winning physiologist A.V. Hill seemed to show that lactic acid could decrease muscular force production, the brain and spinal cord were viewed as just along for the ride, responding meekly to the requests placed by the heart and leg muscles during exercise. If the leg muscles were rollicking along in a steady bath of oxygen, the nervous system sent enough impulses to keep them moving at the requisite rate.

All of this seemed fine until some probing running researchers began to reveal in the 1970s and 1980s that there were other physiological variables that predicted running success. Notably, running economy (i.e., a measure of how stingy runners were with their oxygen) and lactate-threshold velocity (i.e., the velocity above which lactate began to build up in the blood; originally called anaerobic threshold speed) were shown to be relatively reliable predictors of endurance performance.

Limits of $\dot{V}O_2\text{max}$ and the Role of the Nervous System

Making matters much worse for the traditional model, studies began to appear that revealed that $\dot{V}O_2\text{max}$ was a decent forecaster of performance if one were comparing elite runners with runners in the middle of the pack—but it was weak at foretelling race times among similarly trained runners (e.g., elites, subelites, medium-level runners, and novices). How could that be? After all, endurance running was and still is a truly aerobic sport, with oxygen usage supplying 99 percent of the energy required to run a 10K and oxygen limitation seemingly crucial in determining what can happen in races. Flying in the face of the conventional model, some studies even had the audacity to determine that 300-meter (.19 mi) sprint time—a primarily anaerobic activity—could predict endurance performance far more effectively than maximal aerobic capacity, or $\dot{V}O_2\text{max}$.

Thanks to such findings and to brilliant and innovative research, we learned that endurance runners do have nervous systems after all, and that the nervous system plays a profound role in determining the success or failure of both training and competition. The nervous system can create fatigue and actually regulate running pace during endurance training and racing via what is now termed the anticipatory regulation of exercise performance through effort perception. This is part of the revolution in which exercise science is currently immersed. The understanding of the nervous system's role has not only shaken up exercise physiology but has also had a dramatic impact on the training of endurance runners, as the reader will come to understand by reading this book.

The other part of the revolution concerns fatigue itself. Originally thought to be a simple phenomenon related to intramuscular lactic acid, fatigue is now linked with nervous system functioning along with a whole complex of physiological factors such as velocity at $\dot{V}O_2\text{max}$, running economy, lactate-threshold velocity, resistance to fatigue, maximal running speed, intramuscular pH, and even muscular potassium levels. The search for the origins of fatigue during running is an important one: When fatigue is understood, the optimal mode of training to limit that fatigue and thus to optimize performance can be researched and implemented.

Science Sheds Light on Running

As a scientist, I love the fact that an understanding of running performance is approachable via the scientific method and that running science has provided so many valuable clues about optimal training. No longer are we completely bound by tradition and myth: We can look to great research carried out by running scientists around the globe in order to plan our training and prepare for our most important races.

I believe that running is intrinsically tied to science, more so than many other sports. If we attempt to understand why Derek Jeter piled up more than 3,000 hits and why Marv Throneberry struggled so much to hit curve balls and catch soft tosses from his second baseman, we are stymied nearly immediately by the simple process of identifying the key variables that should be examined. In running, the factors important for success have been identified; we simply need to understand how they work together and how they can be optimized by training.

Running science has had a major practical impact on training for improved performance. Thanks to research, runners and coaches now understand how changes in the volume, intensity, and frequency of training impact the key performance variables, including neural drive, $\dot{V}O_2$ max, running economy, lactate-threshold velocity, resistance to fatigue, and maximal running speed. They know which running speeds are best for various types of training and which forms of strength training have the largest positive effect on performance.

Thanks to the establishment of the anticipatory regulation model of fatigue, they also know what to do when extreme tiredness strikes during races: Turn up neural drive instead of turning down speed in response to a perceived crisis in the muscles. With confidence and understanding, runners and coaches can now—thanks to science—properly answer key questions such as: How fast should my work intervals be run today? How many miles should I cover in my long run? How should I set up my overall training program? Answers to these questions and others will be provided in this book.

A Peek Into the Book

I thank Human Kinetics for the opportunity to create this book; I had been wanting to write it for a very, very long time. I am both a scientist and runner. My running career began at the age of 2 when I evaded my mother in a backyard chase and concluded that running was a very joyful and liberating activity. Six decades of running have only enhanced my love of the sport: I run nearly every morning with my Siberian Husky, who defies all hypotheses about fatigue and toys with me during both sprints and long efforts. I am now happily the race director of the Lansing Marathon, the manager of a successful team of elite Kenyan athletes, and the CEO of the nonprofit organization Lansing Moves the World.

Over the past three years, I ran nearly every day during the predawn hours and worked on the organization and content of this book after my workouts. *Running Science* is organized in a unique way. Beginning with a look at the genetics of running performance and the biomechanics of running in parts I and II, it then proceeds to describe the physiological factors that are important for performance (part III). The next unit (part IV) covers different training methods, and part V outlines key variables, such as volume, frequency, and intensity, and offers an overview of recovery techniques, periodization, and

strength training. Part VI explores training for optimizing performance variables, and part VII explains the molecular basis of training. Part VIII discusses how to prepare for popular race distances. The closing sections of the volume address a number of key issues, including the prevention of running injuries and the health benefits of running (part IX); nutritional supplements, proper eating for running, and weight control (part X); and psychological strategies linked with top performance and even the addictive aspects of running (part XI). I sincerely hope you enjoy this book!

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PART

I

Genetics and Running

CHAPTER 1

Running's Nature-Versus-Nurture Debate

The years 2011 and 2012 were extremely exciting for middle- and long-distance running: In 2011, Geoffrey Mutai surged to victory in the Boston Marathon in 2:03:02, the fastest marathon time ever recorded, and fellow Kenyan Mary Keitany blazed a new world record of 1:05:50 in the half marathon. In 2012, David Rudisha stormed to a new world record of 1:40.91 for 800 meters at the London Olympic Games. Each time a Kenyan athlete performs in an astonishing manner, the debate seems to begin anew: Is nature or nurture more important for running success?

Runners, coaches, and exercise scientists often wonder whether running performances are determined primarily by genetic factors or by the environment. Fans of distance running speculate whether the current Kenyan dominance of endurance competitions is the result of genetic superiority or an active childhood at higher altitudes in western Kenya. Weekend runners trouble themselves over whether they have the innate capacity (genetic constitution) to break 40 minutes in the 10K. And coaches and exercise scientists may dream of testing athletes genetically to determine potential at different running distances.

Such concerns are much more than curiosities. If performances are indeed primarily shaped by genes, coaches and serious runners will begin using cheek swabs to learn what their DNA determines about their running futures, and deceptive practices such as gene doping could play a prominent role in elite competitions. If the environment rules over genetic composition, runners will optimistically juggle their training programs in hopes of finding the schedules that produce the best possible personal performances, and serious scientific research will begin on exactly *how* East Africans are achieving such amazing levels of running fitness.

Genetic factors include the presence or absence of genes that have an impact on physical performance as well as the interactions between such genes. A runner's environment is composed of training, dietary practices, and social and geographical factors. Training is much more than the faithful

following of a workout schedule—it is a complex activity including psychological aspects such as willingness to train and social components such as external motivation and the actual opportunity to exercise consistently. Another important environmental factor is whether the knowledge to create a program that can optimize the physiological and psychological variables important for performance exists.

Genes and Running Performance

Environmental factors and the physiological variables associated with performance are so complex that there is a tendency for many to take the simplistic view that genes are dominant in determining running success.¹ A facile view is that genes can act as magic bullets that propel athletes with the right genetic compositions to inevitable success. As an example, *Scientific American* once predicted that performances at the 2012 Olympic Games would depend on the insertion of key genes into the nuclei of athletes' muscle cells.² In a similar vein, a professional rugby team from Australia tested its players for variations in 11 exercise-related genes, believing that training programs specifically suited to each player could then be created.³ Many exercise scientists have come to believe that athletes can be genetically profiled in order to predict their risk of sustaining specific injuries and their suitability for team positions, roles, and subdisciplines in various sporting activities.³ There is a belief that an examination of a runner's genes can yield important information about whether he or she should become a sprinter, a middle-distance athlete, or a marathoner. There is also a common perception that East African runners (primarily from Kenya and Ethiopia) have a monopoly on the genes that code for endurance performance.¹

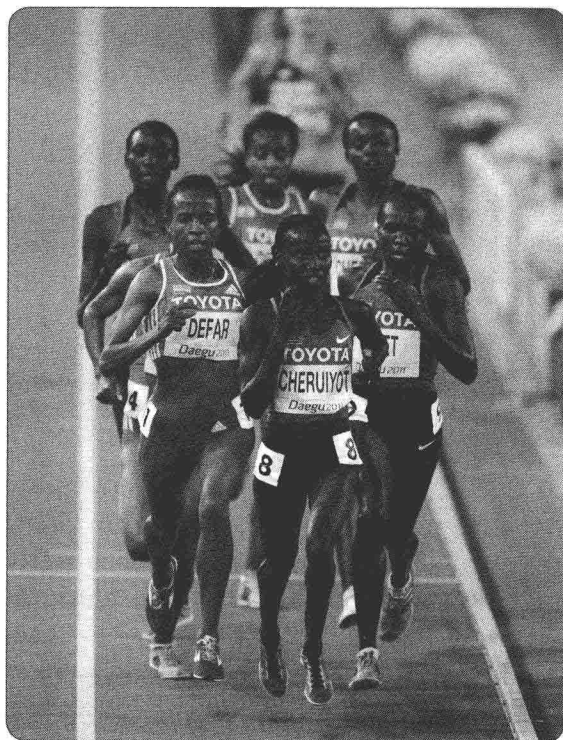
Proponents of a dominant role for genes, or nature, in determining running performances point to the relatively recent discovery of more than 100 genes that have an impact on physical capacity.⁴ Such findings reinforce the idea that an individual's potential for running performance could be largely determined at birth. A runner with the right configuration of this multitude of genes, for example, might have an inborn talent for running that would always elevate him or her above other athletes with less optimal genetic makeup.

At first glance, such thinking does not seem entirely unreasonable. Research has revealed that an individual's genetic makeup has a significant effect on physical characteristics, including body size and shape.⁵ Although there are many exceptions to the rule, the best distance runners tend to be relatively short in stature and light in weight with slim calves, factors that probably have some genetic component. Greater height tends to dampen distance-running performance because of added mass: Bone mass increases exponentially as a function of height, instead of linearly, giving the taller runner relatively more dead weight to move around a 10K or marathon

course. In general, enhanced body mass, either in the form of fat or non-propulsive muscle mass in the upper body, makes endurance runners less economical and less able to sustain high speeds for continuous periods. Scientific studies also have identified many genes that are linked with greater endurance performance.⁶

Somewhat oddly, the East African dominance of distance running is often cited as further evidence that genes are the strongest determinants of endurance performance.⁷ An inescapable fact is that the best middle- and long-distance runners in the world are Africans. Over the last five Olympic Games, from 1996 to 2012, male runners of African origin have captured 11 of the 15 possible gold medals in the 1,500 meters, 5K, and marathon competitions, as well as all 10 gold medals awarded in the 10K and 3K steeplechase events. Males of African origin currently hold 11 of the 12 world records recognized by the International Association of Athletics Federation in events ranging from 800 meters to the marathon, including the 1K, 1.5K, the mile, 2K, 3K, 5K, 10K, 20K, 25K, and the 3K steeplechase.

Such African dominance was not present as recently as 20 years ago when European runners ruled supreme at all competitive distances from 800 meters to the marathon.⁸ In 1987, 58 of the 120 runners on the all-time



Stephane Kempinaire/DPP/Icon SMI

► Elite distance running is dominated by runners from East Africa.