© Daiju Kitamura/AFLO SPORT/Icon SMI

Dai Tamesue trains at Hosei University in Tokyo. Training devices can be used to quantify the work performed during training.

Sample file

heart—a commonly used indicator of the overall physiological stress of a run—in real time throughout each run as well as during recovery periods in runs and at rest. Before the advent of modern heart-rate monitor technologies, there were no tools for physiological measurements that runners could use on their own. They had to go to university laboratories for $\dot{V}O_2max$ tests and other tests.

More recently, a new generation of speed and distance devices based on global positioning system (GPS) and accelerometer technologies has given runners the ability to make accurate and continuous performance measurements in every run. Previously, the best we could do was go to the local track and get split times at the end of every lap or measure road routes with a car odometer and make paint marks at every mile or kilometer.

Heart-rate monitors and speed and distance devices each have several specific uses that help runners train more effectively. But the greatest benefits accrue when runners integrate all of these individual uses within a cohesive system that we call performance management. Chapter 3 presents an overview of the three-step performance management system. Chapters 4, 5, and 6 provide concrete guidelines for executing each of these three steps: monitoring, analyzing, and planning. In this chapter, we focus on the specific uses of heart-rate monitors and speed and distance devices. This is a general overview of the benefits of running and racing with technology. The specific guidelines you will need in order to realize these benefits are detailed in subsequent chapters.

HEART RATE 101

A Finnish company, Polar Electro, developed the first wireless heart-rate monitor in 1977. This device used electrodes contained in a strap worn around the chest to capture the spikes in electrical activity that occur each time the heart muscle

contracts. This captured information was then transmitted to a display watch worn on the wrist, which provided a real-time readout of heart rate. Today's heart-rate monitors offer many more bells and whistles, but they still perform their basic function of monitoring heart rate in the same way.

Heart-rate monitors became very popular among runners, cyclists, triathletes, other endurance athletes, and even general exercisers after the late 1970s. The rationale for their use was readily understood, especially by endurance athletes. Runners, for example, are accustomed to targeting one or more specific running intensities in workouts to stimulate a desired training effect—as each running intensity triggers slightly different physiological adaptations. Heart rate has a well-known positive correlation with exercise intensity. The more rapidly and forcefully the working muscles contract during exercise, the more rapidly the heart muscle must contract to provide enough oxygen to enable the working muscles to continue working as hard as they are trying to work. When consumer heart-rate monitors hit the market, runners immediately recognized these devices as tools enabling them to aim at fairly precise numerical targets in their efforts to perform each run at the correct physiological intensity for the workout's purpose, instead of just going by feel. For example, research has shown that the working muscles metabolize fat as fuel at the highest rate at an intensity that corresponds with 75 to 80 percent of maximum heart rate in the average trained endurance athlete. A runner with a heart-rate monitor can use this knowledge to control his or her pace to stay within this heart-rate zone when performing long runs designed to increase fat-burning ability. This physiological approach enhances endurance because fat is a far more abundant muscle fuel source than the other major muscle fuel, carbohydrate. Fatigue in prolonged efforts often occurs when the carbohydrate stores of the working muscles are depleted. When fat-burning capacity is increased, the runner is able to rely more on fat to fuel running and thereby spare carbohydrate and delay the point of fatigue.

The runners who chose to use heart-rate monitors, their coaches, and exercise scientists who conducted research with heart-rate monitors quickly developed a set of standard uses for the devices. Over the past 20 years or so, these standard uses have evolved slightly to account for certain limitations of heart-rate monitoring as a tool for physiological measurement. And most recently, the advent of speed and distance devices has provided runners with new uses for heart-rate monitoring in its rightful role as an adjunct to pace monitoring.

FOUR USES OF A HEART-RATE MONITOR

Heart-rate monitors have four main uses. Use the device to maintain target heart rates in workouts, track changes in fitness, monitor your recovery status, and quantify the stress of individual workouts.

Sample file

Maintain Target Heart Rates in Workouts

By far the most common use for heart-rate monitors is to facilitate training at the appropriate intensity in workouts. If you know the heart-rate range that is associated with the specific training stimulus you seek in a given run, or segment of a run, then you can check your display watch periodically throughout the workout and adjust your pace as necessary without having to worry about your pace or having to rely entirely on perceived exertion to control your effort. Table 1.1 presents a summary of the primary physiological training effects associated with training at various heart rates.

Table 1.1 Physiological Adaptations Associated With Training at Various Heart Rates

Percentage of maximum heart rate	Physiological adaptation	Fitness benefit
60–70	Increased muscle mitochondria density Increased capillary density Increased aerobic enzyme activity Increased fat oxidation capacity	Increased aerobic capacity (minimal) Increased endurance (moderate)
71–75	Increased muscle mitochondria density Increased capillary density Increased aerobic enzyme activity Increase carbohydrate oxidation capacity Increased muscle glycogen storage	Increased aerobic capacity (minimal) Increased fatigue resistance at moderate paces (moderate)
76–80	Increased heart stroke volume Increased muscle mitochondria density Increased capillary density Increased aerobic enzyme activity Increase carbohydrate oxidation capacity Increased muscle glycogen storage Increased oxygen transport capacity	Increased aerobic capacity (moderate) Increased resistance to fatigue at marathon pace (strong)
81–90	Increased heart stroke volume Increased oxygen transport capacity Increased carbohydrate oxidation capacity Increased neuromuscular coordination Increased lactate shuttling and metabolism	Increased aerobic capacity (moderate) Increased running economy Increased fatigue resistance at half-marathon to 10K pace (strong)
91–100	Increased heart stroke volume Increased fast-twitch muscle fiber recruitment Increased resistance to muscle cell depolarization Increased stride power Increased neuromuscular coordination	Increased aerobic capacity (strong) Increased anaerobic capacity (moderate) Increased speed Increased running economy Increased fatigue resistance at 5K to 1,500 m pace (strong)

Sample file

The earliest attempts to develop target heart-rate training methodologies were aimed at producing one-size-fits-all protocols that worked for people at all fitness levels in every sport. Simple formulas were used to establish heart-rate zones that divided the heart-rate continuum into levels between recovery intensity and maximum intensity. The simplest and most primitive methodology used the formula of 220 beats per minute (bpm) minus age in years to determine an individual maximum heart rate and a table such as table 1.1 to establish individual target heart-rate zones based on the maximum heart-rate value.

It didn't take very long for athletes, coaches, and exercise scientists to discover major flaws in such one-size-fits-all protocols. First of all, it was observed that maximum heart-rate values, as well as the percentage of maximum heart rate (HRmax) that could be sustained for any given time, varied considerably from activity to activity. For example, runners can generally achieve higher heart rates than cyclists, who in turn can achieve higher heart rates than swimmers.

Further complicating matters, testing showed that the formula of 220 minus age was inaccurate for most athletes. What's more, it was discovered that uniform target heart-rate zones based on percentages of maximum heart rate often were not appropriate for individual athletes, and typically became more or less appropriate for individual athletes as their fitness levels changed. For example, some target heart-rate zone tables established lactate threshold heart rate as 81 to 90 percent of HRmax. (Lactate threshold is the exercise intensity level above which lactate begins to accumulate rapidly in the blood, and it usually corresponds to roughly one hour of maximum effort in trained athletes.) There are three major problems with these zones:

Sample file

1. The actual lactate threshold heart rate for any individual athlete is much more specific than a full 10 percentage point range.
2. As a percentage of maximum heart rate, lactate threshold values vary considerably among athletes, from as low as 70 percent of HRmax to more than 90 percent.
3. The lactate threshold heart rate of each athlete changes with his or her fitness level.

Fortunately, a few noteworthy experts have since developed better methodologies for establishing target heart-rate zones that overcome these flaws. One of the best was developed by our colleague Joe Friel. It ignores HRmax completely and instead bases target heart-rate zones on lactate threshold heart rate, which is determined through field testing. The simplest field test for lactate threshold heart rate is to run a 30-minute time trial (after a thorough warm-up) at a steady pace. Your average heart rate for the final 10 minutes is considered your lactate threshold heart rate, although it's actually somewhat higher than the value that

would be arrived at through laboratory testing. You then look up this value on a table for your specific sport—in this case running—which gives you target heart-rate zones for all of the training zones in Friel's system. Following is a listing of the approximate heart-rate range associated with each zone for running. To establish your zones, you would multiply your lactate threshold heart rate (LT HR) by the percentage associated with the bottom and top of each zone.

Zone 1: Active recovery (>80% of LT HR)

Zone 2: Aerobic threshold (81 to 89% of LT HR)

Zone 3: Tempo (90 to 95% LT HR)

Zone 4: Sublactate threshold (96 to 99% LT HR)

Zone 5a: Lactate threshold (100 to 101% LT HR)

Zone 5b: Aerobic capacity (102 to 105% LT HR)

Zone 5c: Anaerobic capacity (>106% LT HR)

The final step in the process is to repeat your lactate threshold field test every few weeks and adjust your target heart-rate zones to match changes in your fitness level.

The advent of speed and distance technology has made possible an even simpler and more accurate way to establish target heart-rate zones. All you have to do is wear your heart-rate monitor while performing pace-based workouts such as those using the pace zone index (PZI) system presented in chapter 4. Press the Lap button on the display watch at the beginning and end of a segment of the run that is performed at a given target pace. After completing the workout, download the data and inspect the graph of each workout to determine the heart rate that is associated with each target pace. Since no single workout ever encompasses every target pace (there are six separate target pace zones in the PZI system), repeat this process in different workouts until you have covered all of the target pace zones and found the heart rate associated with each.

While we recommend that you rely mainly on pace to monitor and control the intensity of your runs, heart-rate zones established through pace-based training can be a good substitute whenever you are unable to train with your speed and distance device.

Track Changes in Fitness

You can use heart-rate monitors in a few different ways to track changes in fitness level. One way is called *orthostatic testing*. Put on your heart-rate monitor, lie down for a few minutes, and note your heart rate. Now stand up, wait 15 seconds, and note your heart rate again. Your second heart-rate measurement most likely will be 15 to 30 bpm higher than the first. If you perform orthostatic testing regularly while training toward peak fitness, the difference between the

Sample file

two measurements likely will decrease as your heart becomes more powerful and efficient.

An alternative to orthostatic testing that you can use in the context of workouts is heart-rate recovery testing. At the end of a run, cool down with easy jogging until your heart rate levels off at a round number, say 120 bpm, and then stop. After stopping, note how long it takes for your heart rate to drop to 100 bpm. As you gain fitness, your heart rate will drop faster. Be sure to use the same starting heart rate each time you repeat the test. The precise heart rate you choose as a starting number is unimportant. It should just be a heart rate within the range associated with your recovery jogging pace. Choosing a round number within this range might make it easier to remember.

There are other ways of using a heart-rate monitor to track changes in your fitness level that require simultaneous performance measurement. One of the more sophisticated ways of combining these two types of measurement involves tracking the alignment of your goal race pace for a particular event and your heart rate at race pace. If you are training to achieve a certain time goal in an upcoming race, a specific pace per mile associated with that time represents your goal race pace. For example, if your goal is to run a 3:10:00 marathon, your goal race pace is 7:15 per mile.

When you run the race, your performance also will be associated with a certain average heart rate. At the beginning of the process of training for this race, when performing race-pace workouts, your average heart rate will be higher, indicating that you are not yet efficient enough at your goal pace to sustain it for the full race distance. As the training process unfolds, you should observe a lowering trend in your average heart rate at this pace. You also can flip it around and perform workouts at your race-pace heart rate (this requires that you have heart-rate data from previous races at the same distance that were run at peak fitness) and look for a trend toward increasing average speed at this heart rate. There is some debate about whether the information derived from this sort of analysis is worth the bother, and in fact we do not use it in our own coaching, but there are some very successful coaches, including Bobby McGee, who do. (Read about Bobby McGee's approach to balancing pace and heart rate in the sidebar.)

Using the software that comes with your device, or an aftermarket product such as Training Peaks WKO+, you can perform this type of analysis with every run. Just download your workout, look at the graph, and note the average heart rate associated with your average pace for a segment of the workout in which you ran at a steady pace. Then go back to a similar workout performed a few weeks earlier and note the pace associated with the same heart rate or the heart rate associated with the same pace. If you're getting fitter, you will find that in your recent workout, you either ran at a faster pace at the same heart rate or had

Sample file