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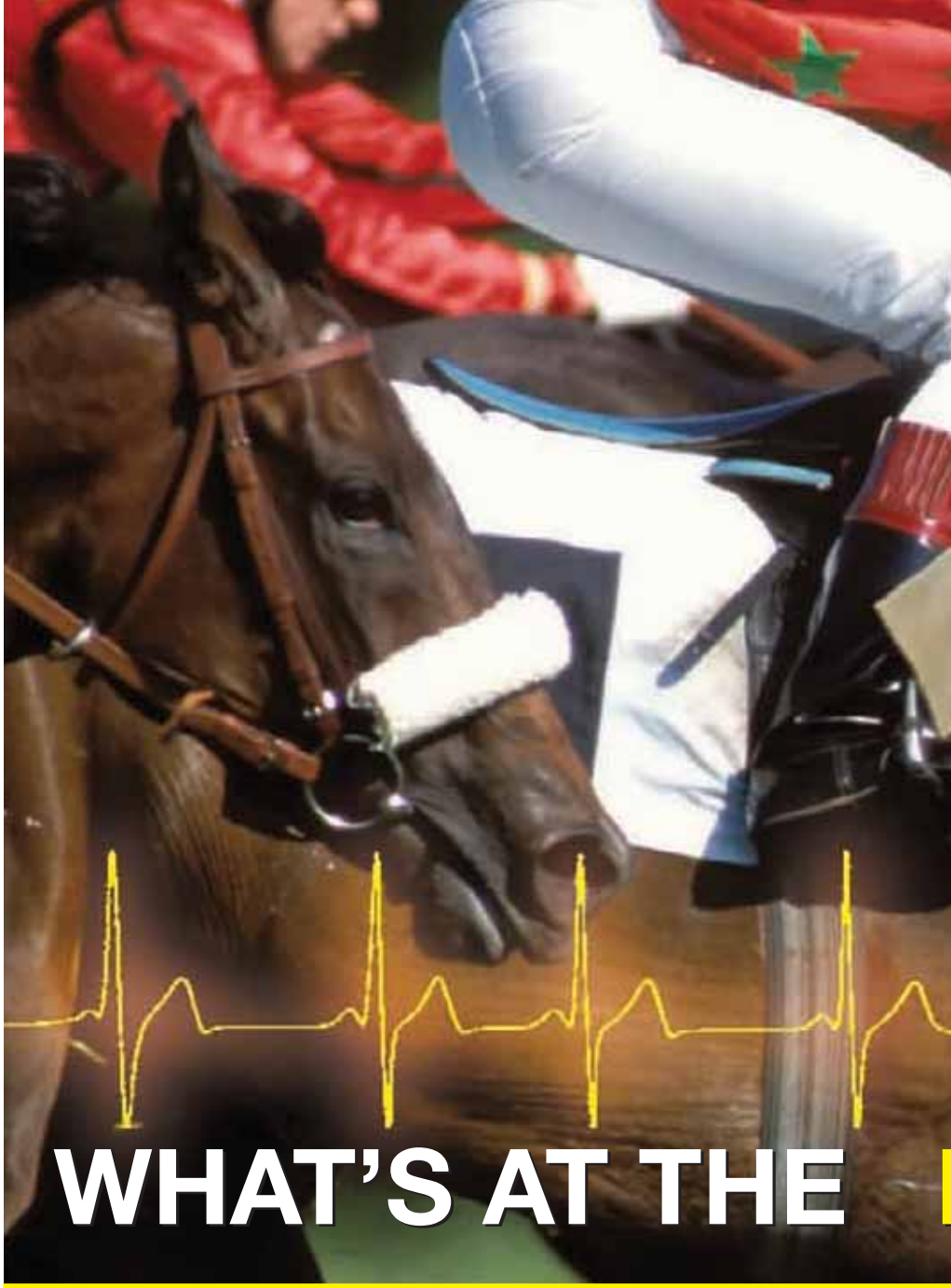
By Christine Ross, DVM,
with Christine Barakat



WHAT'S AT THE

A California practitioner may have found the answer. By analysing the millisecond intervals between heartbeats, she says, it's possible **to predict - and prevent - catastrophic injuries and illness.**

Few sights are as haunting as a racehorse's breakdown. One moment a magnificent athlete is giving his all, the next he's unable to walk, much less run. If he survives the initial insult, he faces months of discomfort and an uncertain future.

In my 23 years as a veterinarian in equine practice, I have often dealt with the aftermath of these injuries. To be sure, research advances have made this task easier. Improvements in fracture stabilisation, surgical repair techniques and postoperative management help many horses survive injuries that were once a death sentence. But, I always wondered, wouldn't it be better if we could prevent breakdowns from happening in the first place? Although these injuries seem like a sudden event, they are actually the culmination of myriad physiological changes that occur over weeks and months. If we could find a way to identify and quantify these changes, perhaps we might be.

Then about seven years ago, I realised there may be a way to do just that. I began investigating applications of heart rate variability (HRV) analysis, the study of the intervals between each beat of the heart, and I found that this technology can provide precise data about a horse's health, fitness and fatigue. With this information, we can determine when horses are being pushed too hard and adjust their training or competitive schedules accordingly. In other words, with HRV analysis we may one day make breakdowns - and fatigue-related illness - in horses very rare events.

HRV EXPLAINED

Heart rate variability describes the time that passes between heartbeats (sometimes called the interbeat interval).

In healthy animals, the length of these intervals varies from one beat to the next

HEART OF BREAKDOWNS?

IMPERCEPTIBLE:

Even horses who appear vigorous and show no sign of being tired may be experiencing physiological fatigue. When this occurs, a horse's ability to resist the forces of gravity diminishes, increasing the peak loading of his supporting structures, which in turn can leave him susceptible to injury.

Unlike arrhythmias - gross abnormalities in the rhythm of the heart that can be heard through a stethoscope - variations in the interbeat interval, measured in milliseconds, cannot be discerned simply by listening to the heart. HRV is determined using complex calculations based on cardiac data collected with sensitive monitoring devices.

Tracking these small changes in the interbeat interval gives us the HRV pattern, which is then analysed using mathematical formulas to yield specific parameters and measurements. It may seem counterintuitive, but more variability in the interbeat interval is better. Heartbeats are controlled by the sinoatrial node, a discrete collection of nerves within the heart. Both the parasympathetic nervous system, which slows the heart, and the sympathetic branch, which speeds it up, continually send signals to the sinoatrial node. Input from these two branches changes from moment to moment, depending on the physiological and emotional state of the animal. Variations in the interbeat interval reflect the heart's ability - and therefore the entire body's capacity - to adapt to these ever-changing inputs. And, in the individual as in the species, adaptation is key to survival.

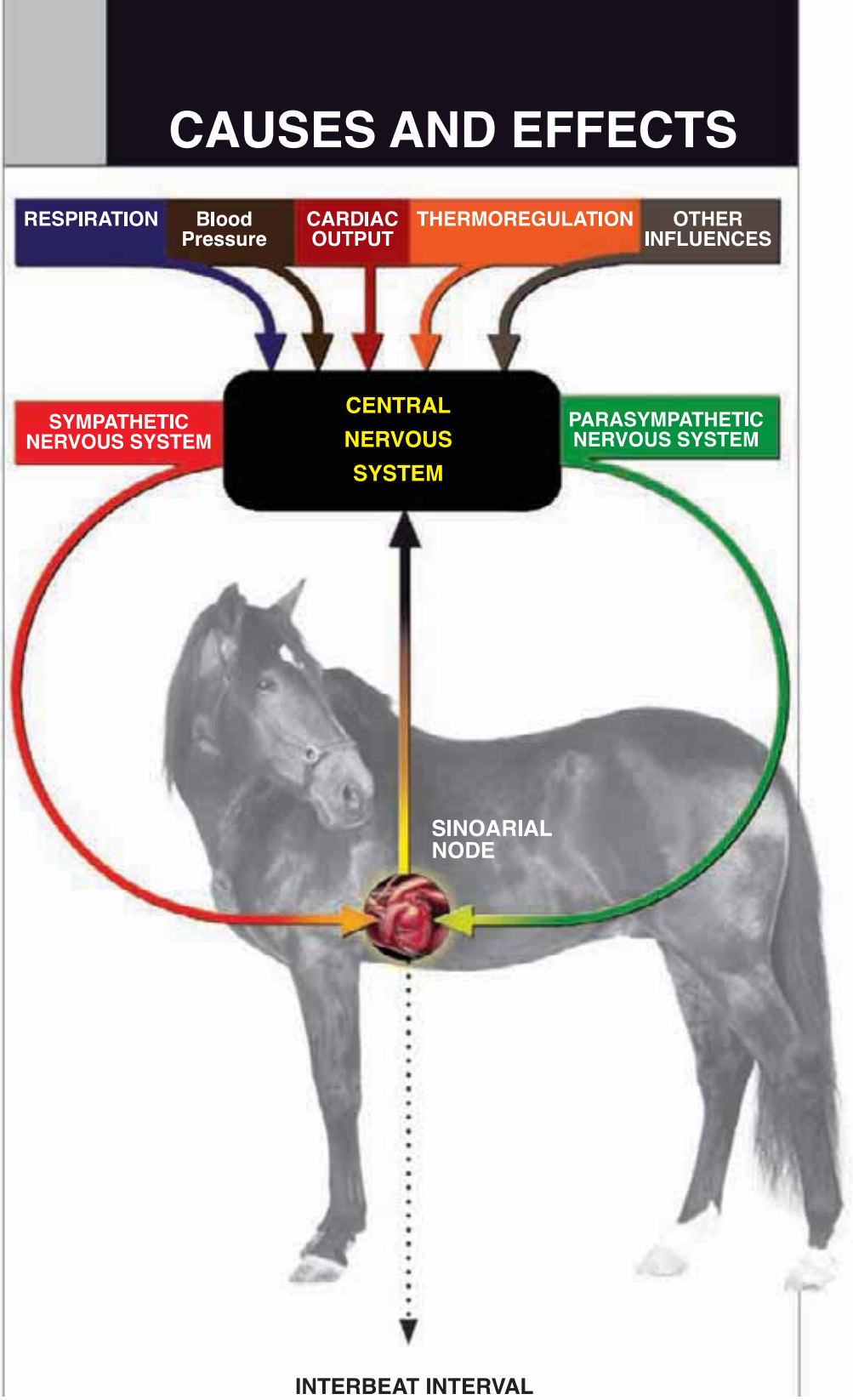
CRACKING THE CODE

Because HRV patterns are essentially a record of the signals sent to and from the central nervous system, they are potentially a rich source of physiological data about an individual. Just as disease "signatures" can be evident in blood panels, certain physiological conditions manifest in HRV, even when there are no outward signs of trouble.

In the late 1960s, for instance, it was discovered that HRV analysis could detect physiological stress in a fetus before a change in heart rate occurred. It soon became, and still is, a key part of fetal monitoring during labour and delivery.

Similarly, HRV analysis can predict the survival rate of cardiac patients: Decreased HRV has been associated

CAUSES AND EFFECTS



The **autonomic nervous system** (ANS), also known as the visceral nervous system, is the part of the peripheral nervous system that regulates heartbeat, glandular secretions and other maintenance activities in the body primarily performed without conscious control or sensation. Respiratory rates, temperature, blood pressure and other physiological information from the **central nervous system** (CNS) affect the parasympathetic and **sympathetic branches** of the ANS. These then influence the **sinoatrial node**, which regulates the horse's heartbeat and interbeat intervals (the time between consecutive beats). The heart rate variability pattern is therefore a summation of many physiological factors within the body.

WHAT "FATIGUE" REALLY MEANS

OVERLOAD: Hyperextension can damage joints, ligaments and tendons.

In veterinary terminology, the term "fatigue" is generally applied only to specific structures. Bone, ligament or tendon, for example, become structurally fatigued to the point of weakening or failure. But before this happens, it"D5s likely that a more widespread process has occurred: physiological fatigue.

Even standing still, your horse uses a great deal of energy just to resist the gravitational pull of the Earth. His core and axial muscles must stabilize and lift his 1000-pound body, along with the weight of the tack and rider, against the pull of gravity with each step. As a horse becomes tired, his ability to lift his body weight and rider decreases, increasing the peak loading of his structures.

This contributes to hyperextension of the limbs and damage to joints, ligaments, and tendons. Like a pile driver, over time, each stride contributes to microcracking and ultimately failure and fractures of the bone. The fracture may indeed be the result of isolated bone fatigue, but I believe that fatigue of the whole horse often precedes fatigue of the bone.

It is important to differentiate this phenomenon from stress, which is essential for conditioning. Stress, in the form of athletic challenge, is an integral part of athletic training: a planned challenge (training) elicits an expected and desired physiological response, a process called adaptation.

Wolff's Law, promulgated by the German anatomist/surgeon Julius Wolff (1835-1902), states that bone in a healthy person or animal will adapt to reasonable loads it is placed under. As loading on a particular bone increases moderately, the bone remodels itself over time to become stronger to resist that size and duration of loading. Conversely, if the loading on a bone decreases, the bone becomes weaker. Without some sort of controlled exercise, bones demineralise. And with excessively severe or repeated loading, maladaptation—the opposite of adaptation—of the bone occurs and failure looms.

In addition, stressors unrelated to training can contribute to fatigue. That's why I believe we must do a better job of assessing fatigue in horses and monitoring it during the training and rehabilitation process.—Christine Ross, DVM.

with a fourfold increase in sudden cardiac death in patients with coronary artery disease.

HRV can also detect general fatigue. One French study found a significant decrease in the heart rate variability of garbage collectors during three consecutive weeks of work, a change that reversed with rest. Interestingly, the HRV readings for that particular study were done at night, while the workers slept, and HRV readings for athletes are done while they are inactive, showing that the effects of fatigue continue long after the inciting event (working or training) is over.

Perhaps most intriguing is the insight HRV analysis can provide about a subject's emotional state. A study of championship chess players found a significant decrease in HRV associated with the feeling of hopelessness after particular moves. Other research has shown that laughing and weeping affect HRV patterns.

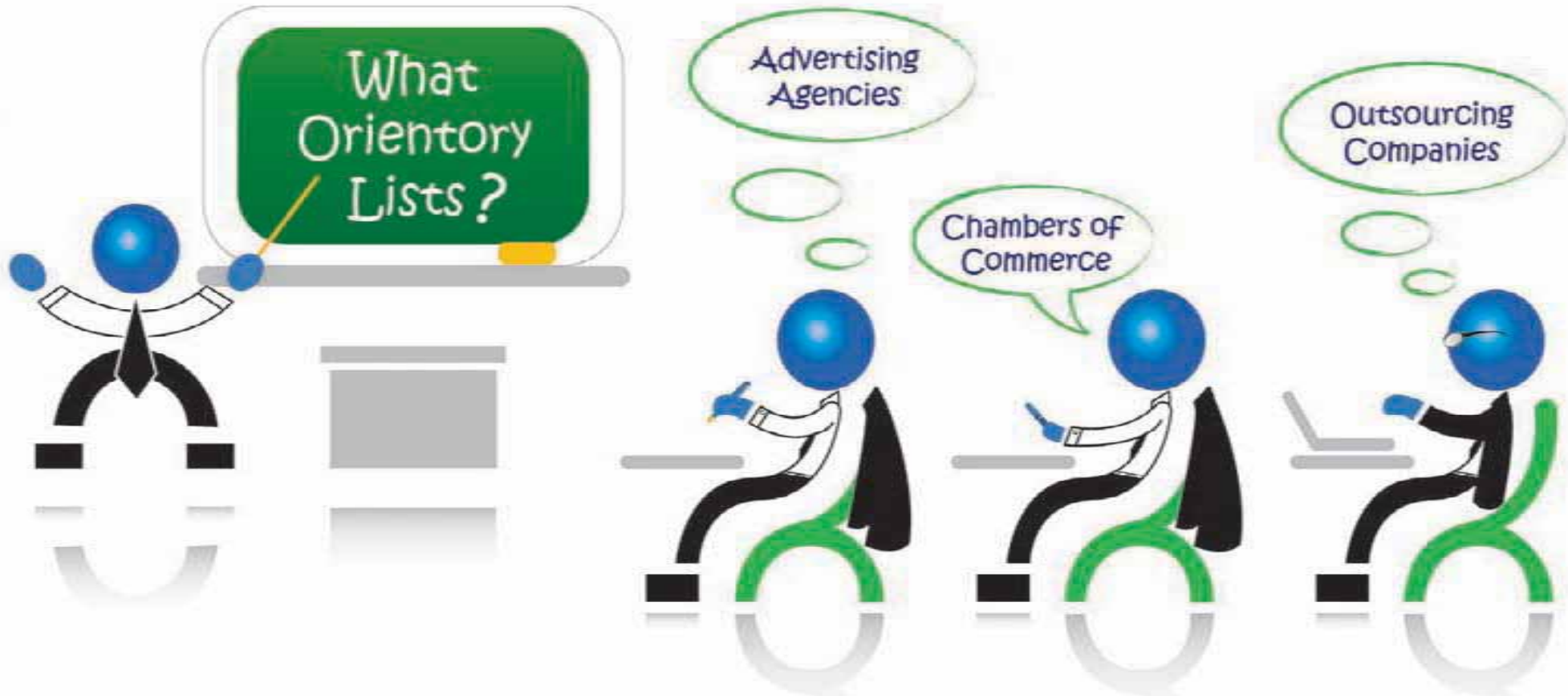
HRV ANALYSIS IN HORSES

The idea of applying HRV analysis in horses occurred to me when I was writing a chapter for a book on new therapies. As I worked, I began to fully realise the importance of the autonomic nervous system - the combined sympathetic and parasympathetic branches, as well as other neurohormonal influences - in all areas of veterinary practice and animal management.

I was familiar with the use of HRV in monitoring human cardiac patients and fetal health, and I began to wonder whether the same technology could produce useful data about horses. Specifically, could HRV analysis correlate specific data parameters directly to clinical conditions in the horse? I was determined to find out.

Over a period of several years, I recorded and computed HRV patterns in more than 600 horses. I placed monitoring equipment on horses while they were at rest in a familiar stall and collected cardiac data for five minutes. I then used HRV analysis software, specifically adapted for my purposes, to calculate an HRV "index" of my own design for each horse.

Comparing that information to the current known physiological state of the horse, determined by an independent veterinarian, I came to an encouraging conclusion: a specific index of HRV parameters - signatures, of sorts - could be correlated directly to known clinical conditions, such as pain, fatigue or systemic illness. The pattern couldn't tell me exactly why the horse was fatigued or in pain or what disease process was present, but it was clear that the horse's physical well-being was reflected in his HRV pattern.



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THE BIGGEST QUESTION

These findings led to two questions with potentially exciting answers: could HRV patterns reveal these problems before they were apparent clinically? And with this data could we actually prevent the impending problem?

To find the answers, I needed to conduct more research. I applied for and received a practitioner's research grant from the Southern California Equine Foundation. With funds provided by the Dolly Green Research Foundation, I embarked on a formal study to test the hypothesis with disinterested third parties selecting the horses, collecting data, conducting clinical evaluations and making predictions based on the HRV patterns I had previously documented.

We used 16 racehorses in training at two separate barns at Southern California Thoroughbred racetracks. There were no outward signs that any were headed toward injury or illness.

THE DATA SHOWED THAT YOU CAN - WITH HIGH PROBABILITY - PREDICT WHETHER A HORSE IS LIKELY TO BECOME INJURED OR ILL SIMPLY BY ANALYSING HIS HRV PATTERN.

Daily over a two-month period, researchers collected heart data from each horse as he rested in his own stall. The data was then transmitted to a computer for HRV analysis and index calculation.

Based on the HRV index I developed in my earlier research, 13 of the study horses had patterns statistically similar to those associated with pain, fatigue, illness or injury. Although these horses appeared perfectly healthy and energetic, they were categorised as "at risk." We then followed the study horses for three months, noting their performance and health status.

Twelve of the 13 at-risk horses sustained an injury or developed an illness that required veterinary intervention and/or halted race training. Only one of our 16 assessments was incorrect, and we had no "false positives."That is, we did not miss any at-risk horses. This was due in part to the fact that we purposefully calculated the index with a high degree of sensitivity - at the outset we decided we would rather flag a horse that did not have a problem than miss one that did with potentially catastrophic consequences.

The data showed that you can - with high probability - predict whether a horse is likely to become injured or ill, up to three months ahead of time, simply by analysing his HRV pattern. Our results are still unpublished, but we'd like to gather data from a larger group of horses and continue to improve our models for HRV patterns that indicate problems. Currently, we are seeking funding for a large-scale follow-up study. Patent applications on these techniques have been submitted; one has recently been approved.

HRV AND YOUR HORSE

Although our studies focused on racehorses, others can also benefit from HRV analysis. Show horses, for example, often have rigorous training and transport schedules that can quickly lead to health- and soundness-threatening fatigue. At the other end of the spectrum are "weekend warrior" pleasure horses, who spend much of their time standing in stalls until we have time to ride. Is your pleasure horse really fit enough for that three-hour weekend ride? At what point during that trail ride does your horse's fatigue predispose him to injury?

It's the nature of horses to perform when asked, so we rarely even suspect fatigue until it leads to diminished performance, illness or breakdown. There are few and feeble tests that can tell us that a horse is overmatched or help us measure his ability to manage his workload. HRV analysis could provide this missing link.

My hope is that my work with heart rate variability analysis, along with advances in technology, telemetry and wireless communication, will one day make it possible to track your horse's fitness and fatigue levels. I envision an owner connecting, via computer or cell phone, to a small sensor on his or her horse and receiving a real-time HRV report, depicting clinical status. Better yet, your horse could wear a small sensor that would be set to call you when he is in distress, in pain, fatigued or systemically compromised. In that way, through HRV analysis, horses will have a voice in their own care.

BEYOND THE RACETRACK: Someday it may be possible to use HRV analysis to detect fatigue in show and pleasure horses before problems develop.

ABOUT THE AUTHOR: *California native Christine Ross, DVM, has worked in the racing industry since the early 1970s. After earning her degree from Kansas State University School of Veterinary Medicine, she interned at Chino Valley Equine Hospital in Southern California. After a stint in Australia, she established a private practice in Del Mar, California, in 1992. She now lives in Rancho Santa Fe with her son Erik, three dogs, five cats and a rabbit.*