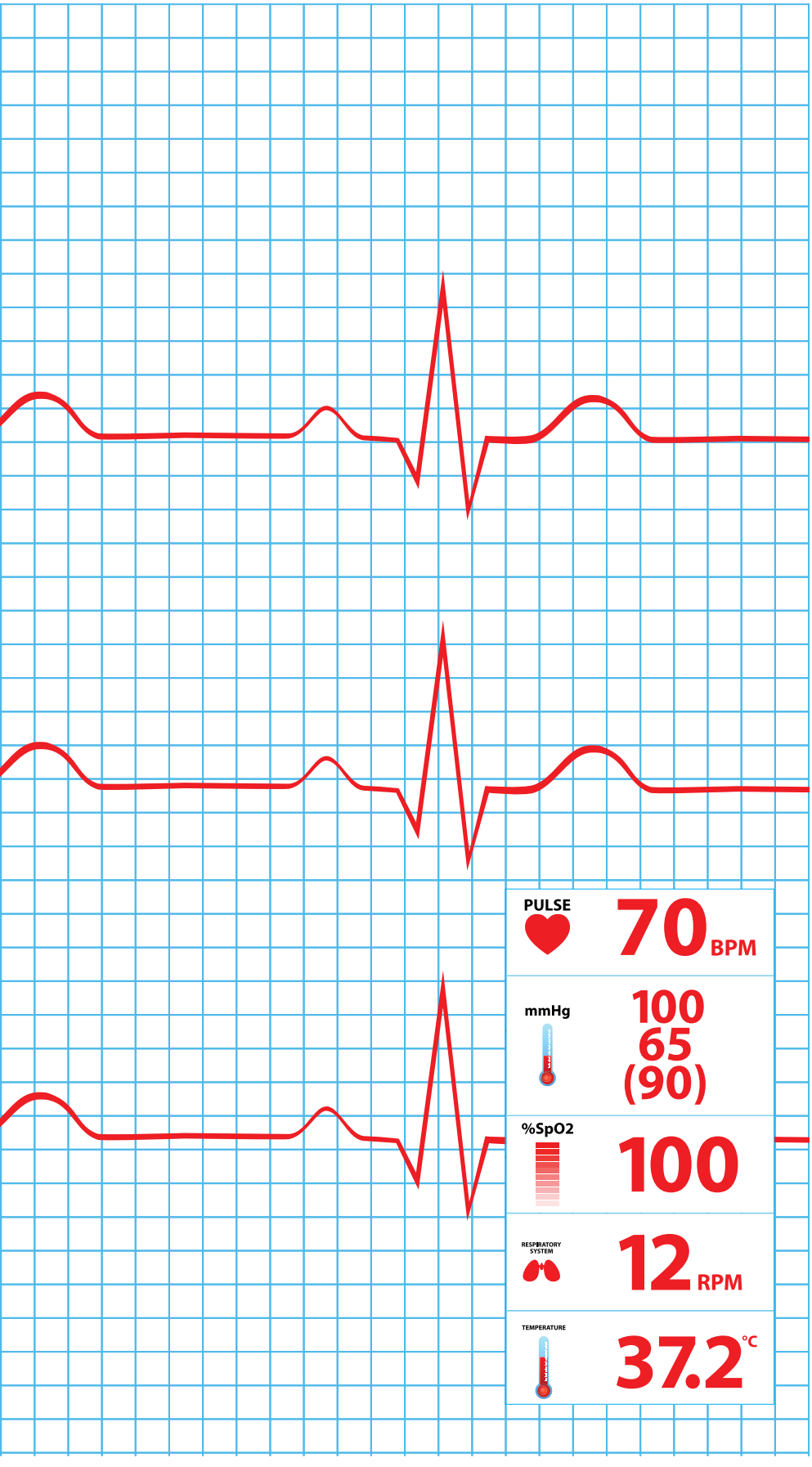
HEART RATE VARIABILITY & OVERTRAINING



CAN NEW RESEARCH PREVENT AN AGE-OLD PARADIGM?

By Trisha Ann VanDusseldorp, MS, and Len Kravitz, PhD

Heart rate variability (HRV) is a reliable marker of physiological factors that directly affect the rhythms of the heart (Acharya et al. 2006). Acharya and colleagues explain that HRV reflects the heart's ability to adapt to changing circumstances—stress, exercise and disease—by balancing the regulation of the autonomic nervous system, which controls bodily functions such as breathing, heartbeat and digestion.

Exercise training status, including overtraining, can play a key role in HRV (Achten & Jeukendrup 2003). Chronic overtraining often leads to physiological and psychological symptoms that impair performance and delay full recovery for weeks or more (Meeusen et al. 2013). For personal trainers, an understanding of the relationship between HRV and overtraining, including a deeper grasp of the potential mechanisms and prevention strategies of overtraining, is paramount for helping clients achieve optimal gains in cardiorespiratory efficiency. >>

What Is HRV, and What Does It Tell Us?

HRV describes fluctuations in consecutive heartbeat intervals above and below an average heart rate over a period of time; in clinical settings, the measurement time might range from 5 minutes to 24 hours (Acharya et al. 2006). HRV is particularly influenced by the autonomic nervous system (Acharya et al. 2006), which comprises the **sympathetic nervous system (SNS)** and the **parasympathetic nervous system (PNS).**

The SNS mobilizes the body's hormones and nerves to respond speedily to exercise, stress and fight-or-flight situations--enabling a person to run across the street quickly to avoid an oncoming car, for example, or to respond swiftly to the onset of a thunderstorm. Conversely, the PNS has a slowing effect on heart rate, which helps the body to conserve energy; this system plays a strong role in bodily function homeostasis, including digestion and gland activity. The unique and different contributions of the SNS and PNS mildly modify the intervals between heartbeats, or HRV (see Figure 1).

For scientists, coaches and personal trainers, HRV measurements—called **R-to-R wave intervals**—are useful markers for understanding the status of the autonomic nervous system and can be used to clinically detect cardiac health and client readiness for intensity and volume progressions in exercise training.

Clinical Applications of HRV Analysis

Acharya et al. (2006) say HRV measurements are noninvasive and most reliable when performed under standardized conditions. Research suggests that low HRV is a negative outcome of cardiovascular diseases, diabetic neuropathy, elevated blood pressure and heart attack (Stauss 2003). HRV is also useful in observing people with diabetes, which can cause severe dysfunction of the autonomic nervous system (Acharya et al. 2006). Low HRV may point to the onset of diabetic neuropathy, a complication of diabetes mellitus characterized by widespread breakdown of small nerves in the sympathetic and parasympathetic nerve tracts (Malik et al. 1996).

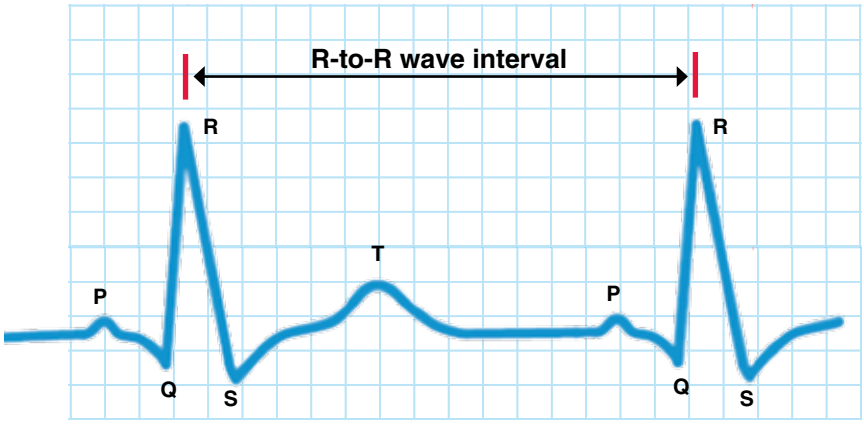
Smoking and alcohol consumption also affect HRV. Acharya and colleagues (2006) conclude that smokers have a depressed HRV, possibly a direct effect of how smoking impairs cardiovascular function, which the autonomic nervous system regulates (Archarya et al. 2006). Malpas, Whiteside & Maling (1991) studied HRV in 23 alcohol-dependent men and found it was significantly lower than in the non-alcoholic (healthy) control group.

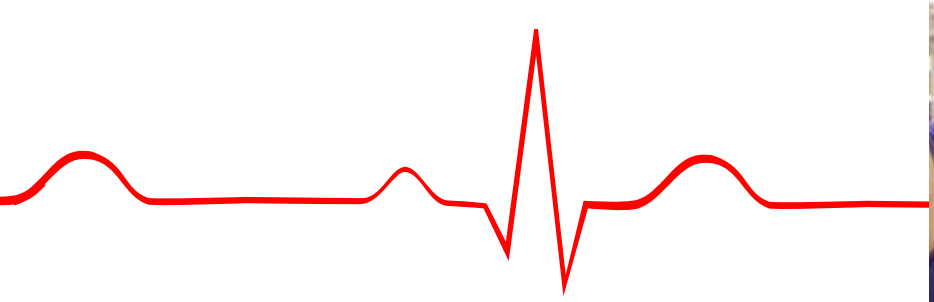
HRV and Exercise: New Technologies

Some new technologies such as www.omegawave.com and www.bioforcehrv.com are using HRV to evaluate athletes' readiness for exercise performance. Smartphone apps with heart rate monitors can measure HRV readily and conveniently, which means coaches, personal trainers and clients can easily monitor the cardiac, metabolic and central nervous systems to more accurately determine the best times to overload with intensity and/or workload volume (or both) and the best times to focus on recovery.

This allows personal trainers and coaches to better balance training progressions and recovery to avoid overtraining and declining performance. While HRV technologies were developed to identify risk levels for cardiac death and diabetic neuropathy, today they are gaining great interest and use in sports physiology and exercise. The main goal of the latest HRV technology is to promote positive overload and adequate recovery, preventing the deleterious effects of overtraining (Pichot et al. 2002). A deeper understanding of overtraining prevention is evolving, which may in turn lead to higher levels of successful training.

FIGURE 1. R WAVE TO R WAVE MEASUREMENT USED FOR HRV CALCULATION



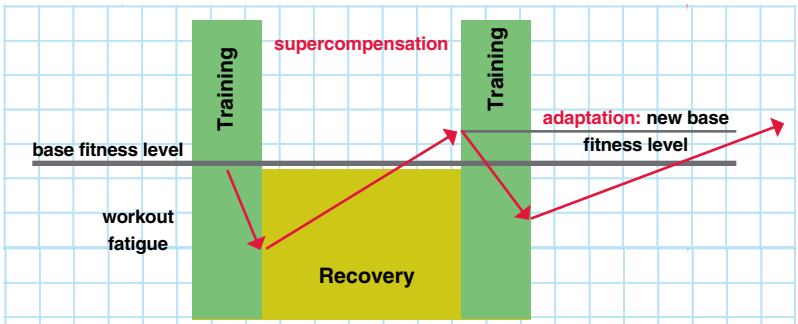


Overtraining in Exercise

Personal trainers regularly monitor clients' physiological and psychological responses to progressive overloads during a training program. After sufficient recovery from training fatigue, the body compensates by building strength and improving performance (see Figure 2).

Overtraining can be an unfortunate consequence of progressive overload. Some people believe overtraining is unique to trained, elite athletes, but trainers need to set clients straight: Successful training includes overload, but not in excess, and it requires adequate recovery, which many clients sacrifice in their quest for immediate results.

FIGURE 2. WORKOUT/RECOVERY SEQUENCE OF TRAINING



In a normal course of exercise training and recovery, progressive training overload leads to positive adaptations and improvements in performance, such as greater aerobic capacity, weight loss, muscle hypertrophy or strength gains.

Source: Meeusen et al. 2013.

How to Define Overtraining

The phenomenon of overtraining syndrome, often called "burnout" or "staleness," has motivated many researchers to investigate its causes and consequences. First, the researchers had to decide on a common title—in the past, OTS was called underperformance syndrome and sports fatigue syndrome (Armstrong & VanHeest 2002). To provide researchers and practitioners with standard language, Meeusen et al. (2013) recently proposed the following terminologies and definitions (see Figure 3).

- **Overtraining** is a process of intensified training leading to possible short-term outcomes of overreaching (called functional overreaching), extreme overreaching (called nonfunctional overreaching) or overtraining syndrome.
- **Functional overreaching** is a short period of increased training leading to a temporary performance decline. With satisfactory recovery, overreaching can lead to what Meeusen et al. (2013) call a "supercompensation" effect of enhanced performance.
- **Nonfunctional overreaching** is a longer process of intense training leading to stagnation and sustained performance decline that can last weeks or months (Meeusen et al. 2013). However,

10 WAYS TO PREVENT OR COMBAT OVERTRAINING IN A CLIENT

A client who develops overtraining syndrome needs to return to a healthy state as fast as possible. While there is no magic cure for overtraining, these 10 preventive strategies for nonfunctional overreaching and overtraining syndrome, from Kreher and Schwartz (2012), should prove helpful:

1. **Education the client. Emphasize that enhanced recovery will allow the client to train more and improve his or her overall fitness.**
2. **Incorporate periodization training, which provides for planned recovery and variation in intensity and volume.**
3. **Sensibly adjust workout volume and intensity based on the client's performance or mood level.**
4. **Ensure that the client is consuming adequate calories for training load. Meeusen et al. (2013) suggest that factors such as dietary caloric restriction, insufficient carbohydrate and/or protein intake, iron deficiency and magnesium deficiency can trigger OTS.**
5. **Ensure that the client is hydrating sufficiently for workout conditions and training load.**
6. **Ensure that the client is getting adequate sleep.**
7. **Ensure that rest periods of >6 hours occur between exercise bouts.**
8. **Encourage rest days following infection, exercise heat stress, and/or periods of high emotional stress.**
9. **Avoid extreme environmental exercise conditions.**
10. **Consistently monitor the client's moods (is she or he tense, angry, unhappy, confused, grouchy, panicky, uneasy, miserable, bitter, exhausted, annoyed, weary, peeved, depressed, on edge, etc.?) and alter workouts as needed.**

FIGURE 3. UNDERTRAINING, OVERREACHING, OVERTRAINING SYNDROME

Sources: Adapted from Armstrong & VanHeest 2002 and Meeusen et al. 2013.

full recovery happens after satisfactory rest.

- **Overtraining syndrome** is a "prolonged maladaptation" that disrupts hormonal, biological and neurological regulatory mechanisms; these physiological consequences are accompanied by mood disturbances (Meeusen et al. 2013). Uniquely, Armstrong and VanHeest (2002) observe that OTS and clinical depression involve remarkably similar signs and symptoms, brain structures, neurotransmitters, endocrine pathways and immune responses.

What Overtraining Looks Like

A plethora of research has focused on identifying and assessing the physiological and psychological changes associated with overtraining, but not all studies measure the same variables, and those that do don't always find the same results.

It is therefore important to note that no single overtraining marker or group of overtraining markers has been identified for a positive diagnosis of overtraining (Meeusen et al. 2013). Initially, there is some decline in performance. As presented in Figure 4, several common signs and symptoms are associated with overtraining.

Armstrong & VanHeest (2002) say that with endurance sports, OTS is characterized by persistent fatigue and apathy. The authors also note that fatigue is associated with illnesses such as anemia, Lyme disease, mononucleosis, hypoglycemia, hypothyroidism and chronic fatigue syndrome.

Several changes in the blood are observed with OTS, including decreases in hematocrit (the ratio of the volume of red blood cells to the total volume of blood), hemoglobin, iron and ferritin (Armstring & VanHeest 2002). Ferritin is a protein that stores iron. Its levels can be used to measure the body's iron levels indirectly. Low levels of ferritin are seen when iron is deficient. With insufficient iron, the body cannot produce enough **hemoglobin,** the component of red blood cells that carries oxygen. Iron deficiency anemia may result, raising the likelihood of fatigue, dizziness and elevated resting heart rate from overtraining (Wyatt, Donaldson & Brown 2013).

Wyatt, Donaldson and Brown (2013) say testosterone levels decline with OTS. Testosterone serves a vital role in the body as an anabolic agent that boosts growth in tissues. Testosterone also promotes many metabolic activities, including the stimulation of protein synthesis and red cell production. The authors say that lower testosterone levels lead to less protein synthesis and decreased production of red blood cells, thus delaying recovery from exercise. OTS also changes the concentration of other hormones, such as norepinephrine, epinephrine, hemoglobin, cortisol and leptin (Wyatt, Donaldson & Brown 2013).

With immune function, one area of interest with OTS is **glutamine,** the most abundant free amino acid in the body. Glutamine is produced in the muscles and is used extensively by the cells of the immune system to support production of **lymphocytes,** white blood cells that defend the body against cancerous cells, pathogens and foreign matter. Wyatt, Donaldson & Brown (2013) say that the lower glutamine levels observed with OTS weaken immune function by altering the function of lymphocytes.

Note: Signs and symptoms of overtraining are highly individualized and subjective, so they cannot be universally applied.

How to Prevent Overtraining Syndrome

Exercise professionals must remember that the underlying causes of overtraining are not fully understood.

7 POSSIBLE CAUSES OF OVERTRAINING

Conducting primary research studies on the causes of overtraining is difficult because it's unethical to induce overtraining syndrome, which can damage a person's performance for months. Kreher and Schwartz (2012) reviewed previously published overtraining research and summarized seven hypotheses (see Figure 5) for mechanisms that cause overtraining syndrome.

HYPOTHESIS #1: AUTONOMIC NERVOUS SYSTEM IMBALANCE

This represents an imbalance between the parasympathetic and sympathetic nervous systems, which directly impacts HRV. In overtrained athletes, decreased HRV on waking may disrupt normal modulation of the autonomic nervous system. Balance between sympathetic and parasympathetic forces may be restored after a week of rest (Pichot et al. 2002).

HYPOTHESIS #2: OXIDATIVE STRESS

Excessive oxidative stress leads to muscle damage and muscle fatigue. Oxidative stress is a disruption in the balance between the production of reactive oxygen species (like free radicals) and antioxidant defenses in the cells that neutralize free-radical buildup.
Skeletal muscle is the body's largest consumer of oxygen and is vulnerable to oxidative stress. Oxidative stress can cause damage to mitochondrial proteins, cell membranes and even DNA (Sayer et al. 2013).

HYPOTHESIS #3: GLYCOGEN DEPLETION

Low levels of muscle glycogen may impair performance if a person's diet is inadequate for the amount of exercise they are performing. Kreher and Schwartz (2012) say some research suggests that glycogen depletion can alter the synthesis of central neurotransmitters involved in fatigue.

HYPOTHESIS #4: CENTRAL FATIGUE

Overtraining often disrupts mood, sleep and behavior. The central fatigue hypothesis proposes that the central nervous system is not providing adequate drive to recruited working muscles. Kreher and Schwartz (2012) say central fatigue results from numerous physiological changes, including increases in brain levels of tryptophan (an essential amino acid involved in protein biosynthesis), decreased branched-chain amino acid (BCAA) concentrations, and increased synthesis of serotonin (a neurotransmitter) in the brain.

HYPOTHESIS #5: GLUTAMINE DEPLETION

:Glutamine is important for immune function. Glutamine also plays a role in DNA synthesis, acid-base balance, and gluconeogenesis--making new glucose or energy for exercise. Low plasma glutamine concentrations have been reported in overtrained individuals (Halson & Jeukendrup 2004).

HYPOTHESIS #6: INCREASED INFLAMMATION

The increased inflammation or cytokine hypothesis suggests that overtraining syndrome is a physiological adaptation or maladaptation to excess stress initiated by an imbalance between training and recovery (Smith 2000). Those who train at a very intense level for long periods of time without adequate rest may enter a state of chronic inflammation with high levels of cytokines. This chronic inflammation has been highly correlated with overtraining syndrome (Smith 2000).

HYPOTHESIS 7. DYSREGULATION OF THE HYPOTHALAMUS

Kreher and Schwartz (2012) summarize several studies indicating that cortisol, testosterone and other hormones regulated by the hypothalamic-pituitary-adrenal and hypothalamic-pituitary-gonadal axes may be altered when clients (especially endurance exercise clients) are overtraining.

FIGURE 4. COMMON SIGNS AND SYMPTOMS ASSOCIATED WITH OVERTRAINING

- declining performance
- insomnia and sleep disturbances
- persistent fatigue and apathy
- disrupted heart rate variability
- stress, irritability and restlessness
- lack of mental concentration
- change in appetite
- persistent muscle soreness
- loss of body mass

Sources: Armstrong & VanHeest 2002; Acharya et al. 2006; Wyatt, Donaldson, & Brown 2013.

Clients who are struggling with anemia often present similar symptoms to those who are overtraining. The OTS Indicator Checklist (see sidebar) has been adapted from the OTS consensus statement article by Meeuson et al. 2013. Personal trainers can use this checklist to help identify or prevent OTS in clients. It is commonly accepted that the presence of one or more symptoms is sufficient to alert a personal trainer that a client may be overtraining (Wyatt, Donaldson & Brown 2013).

Meeusen and colleagues (2013) suggest that personal trainers and coaches must try to exclude organic disease as the cause of declining performance. Possibilities include allergies, anemia, infectious diseases, eating disorders, adult-onset asthma, cardiovascular system conditions, diabetes, thyroid problems, adrenal gland problems and any biological abnormalities. Exercise professionals may need to encourage clients to see a doctor to rule out any of these illnesses. Also, Meeusen et al. (2013) emphasize that athletes require adequate rest and sufficient sleep. The absence of one full passive recovery day each week (during intensified training) is closely related to the signs of overtraining, according to these authors.

Final Thoughts on HRV and Overtraining

With advances in HRV, personal trainers can now noninvasively monitor the cardiac, metabolic and central nervous systems to better determine when it is appropriate to overload with intensity and/or workload (or both), and when it is best to train more lightly and focus on recovery.

Clients with overtraining syndrome will likely display one or more of the following: disrupted heart rate variability, performance declines, persistent fatigue, hematologic changes, hormone concentration changes, impaired immune function, persistent muscle soreness, loss of body mass, apathy, lack of motivation, loss of appetite, sleep disturbances (restless sleep), high stress levels, irritability, depression, attitude changes and a tendency to become easily distracted. Relieving

OTS INDICATOR CHECKLIST

Personal trainers are encouraged to use this OTS Indicator Checklist to help identify or prevent OTS in clients. Although this list was developed from scientific research, there currently is no research consensus on how many of these factors must be present (and to what degree) to confirm OTS.

PERFORMANCE AND FATIGUE INDICATORS

These may be symptoms of OTS:

- __ consistent underperformance
- __ chronic fatigue or symptoms of burnout
- __ continual muscle soreness
- __ insomnia or sleep disturbances
- __ consistently (2 or more mornings) elevated resting heart rate (increase of ≥5 beats/minute measured 5–10 minutes after awakening)

EXERCISE TESTING INDICATORS

- __underperformance on certain submaximal or maximal performance factors
- __ drifting above or below known baseline values (such as rating of perceived exertion and heart rate at certain exercise intensities) during exercise
- __ with endurance training clients, training below normal anaerobic threshold or fixed pace of exercise

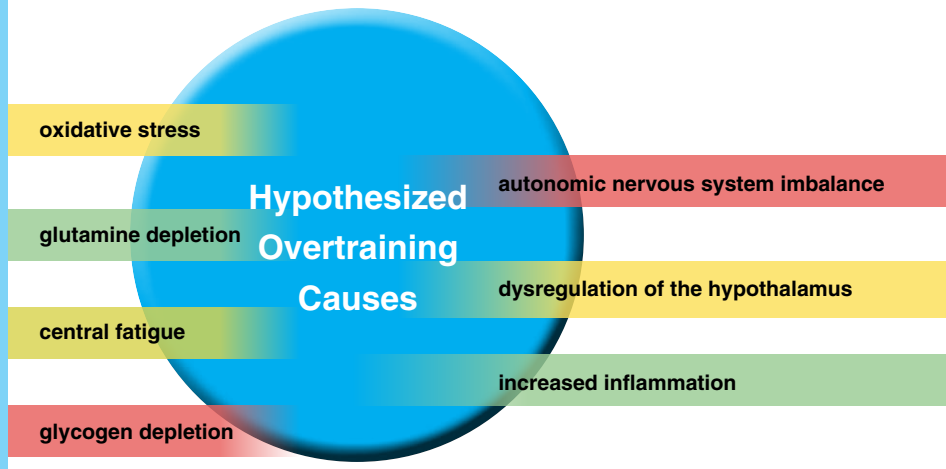
TRAINING INDICATORS

- __entering a high number of competitions
- __ workouts becoming somewhat repetitive (or monotonous)
- __ significant increases in exercise intensity
- __ significant increases in exercise volume
- __ exposure to environment stressors such as altitude, heat, humidity or cold

OTHER CONFOUNDING INDICATORS

- __changes or disruptions in family, personal or social relations
- __ new job-related demands
- __ elevation of negative moods such as tension, depression, anger, confusion
- __ decrease in positive mood or vigor during periods of intense training
- __ change in body weight, particularly loss of lean body mass
- __ changes in diet or appetite
- __ change in hydration status

FIGURE 5. SEVEN HYPOTHESES OF MECHANISMS CAUSING OVERTRAINING



overtraining may be aided by reducing daily training volume or intensity, resolving conflicts that may be adding stress, improving diet and/or taking a recovery break from training if conditions are problematic. ■

Trisha Ann VanDusseldorp, MS, CISSN, is a doctoral student in the health, exercise and sports sciences department at the University of New Mexico, Albuquerque. Trisha is passionate about studying the cellular and molecular responses to supplementation and nutritional interventions, while also examining changes in muscular strength/power and muscular endurance.

Len Kravitz, PhD, is the program coordinator of exercise science and a researcher at the University of New Mexico, Albuquerque, where he has won the Outstanding Teacher of the Year award. He was honored with the Can-Fit-Pro Lifetime Achievement Award in 2008 and received the 2010 Aquatic Exercise Association Global Award.

References can be found on our website, www.ideafit.com.

References

Acharya, U.R., et al. 2006. Heart rate variability: A review. *Medical & Biological Engineering & Computing, 44,* 1031–51.

Achten, J., & Jeukendrup, A.E. 2003. Heart rate monitoring: Applications and limitations, *Sports Medicine, 33* (7), 517–38.

Armstrong, L.E., & VanHeest, J.L. 2002. The unknown mechanism of the overtraining syndrome: Clues from depression and psychoneuroimmunology. *Sports Medicine, 32* (3), 185–209.

Kreher, J.B., & Schwartz, J.B. 2012. Overtraining syndrome: A practical guide. *Sports Health, 4* (2), 128–38.

Malik, M., et al. 1996. Heart rate variability: Standards of measurement, physiological interpretation, and clinical use. *European Heart Journal, 17,* 354–81.

Malpas, S.C., Whiteside, E.A., & Maling, T.J. 1991. Heart rate variability and cardiac autonomic function in men with chronic alcohol dependence. *British Heart Journal, 65* (2), 84–88.

Meeusen, R., et al. 2013. Prevention, diagnosis and treatment of the overtraining syndrome: Joint consensus statement of the European College of Sport Science and the American College of Sports Medicine. *European Journal of Sport Science, 13* (1), 1–24.

Pichot, V., et al. 2002. Autonomic adaptations to intensive and overload training periods: A laboratory study. *Medicine & Science in Sports & Exercise, 34* (10), 1660–66.

Sayer, A.A., et al. 2013. New horizons in the pathogenesis, diagnosis and management of sarcopenia. *Age and Ageing, 42* (2), 145–50.

Smith, L.L. 2000. Cytokine hypothesis of overtraining: A physiological adaptation to excessive stress? *Medicine & Science in Sports & Exercise, 32* (2), 317–31.

Stauss, H.M. 2003. Heart rate variability. *American Journal of Physiology. Regulatory, Integrative and Comparative Physiology, 285* (5), R927–31.

Wyatt, F.B., Donaldson, A., & Brown, E. 2013. The overtraining syndrome: A meta-analytic review. *Journal of Exercise Physiology (online), 16* (2), 12–23.