WHOOP

HEART RATE VARIABILITY –
A COACH'S REVIEW OF THE USES
AND VALUE OF HRV DATA IN ATHLETES

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Table of Contents

Heart Rate Variability

The human heart beats at a non-constant rate; heart rate variability (HRV) is a statistical measurement of heart rate irregularity. Originally used as a predictor of survival after acute medical emergencies, the application of HRV has rapidly expanded, and it has now one of the most studied areas of physiological response to exercise. HRV has been shown in numerous studies to positively correlate with athletic performance and training adaptation, and to negatively correlate with risk of overtraining and injuries. This document provides coaches with an overview of HRV with a focus on its utility as an athlete training tool.

Heart Rate Variability - The Basics

Heart rate variability (HRV) is a measure of irregularity in the heart rate. Consider an oft quoted resting heart rate of 60 beats per minute; this might seem to imply that the heart is beating once a second, when in fact, beat to beat times could range from ½ a second to 2 seconds.

The time between heartbeats, **called an RR-interval**, is named for the heartbeat's R-phase, the most readily distinguished phase of a cardiac muscle contraction.

On an electrocardiogram (ECG or EKG), a series of heartbeats might look something like Figure 1.1 below. Notice that the first RR-interval (between R_1 and R_2) is significantly shorter in time than the second (from R_2 to R_3). This is normal.
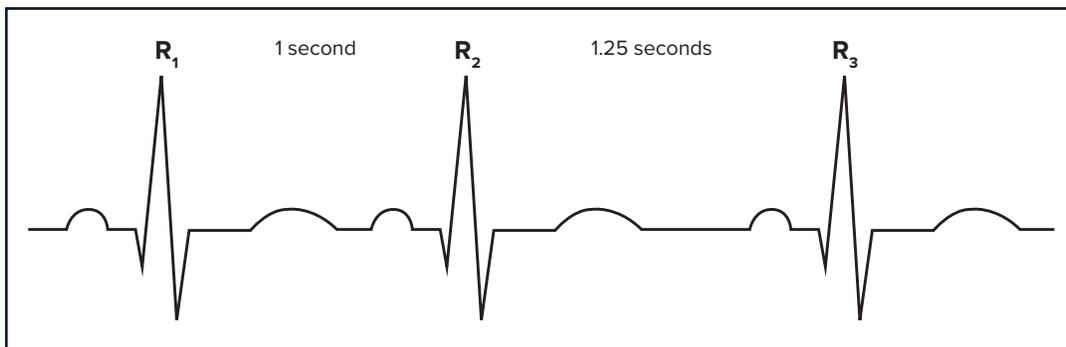

Figure 1.1 Idealized ECG Output

HRV is a measurement of the difference in the lengths of successive beats in a series of RR-intervals, and is typically calculated from a sample of 2 to 5 minutes of heart rate data. Dozens of formulas exist to calculate HRV from RR-intervals, and nearly all share this common foundation.

All Systems "Go"

Although scientists measure HRV as a function of heart rate dynamics, the signal that creates the variability in cardiac muscle contraction timing originates in the nervous system.

HRV measures therefore provide insight into **nervous system function** that provides unique information from that of the measurement of heart rate[1,2].

The human autonomic nervous system controls the involuntary aspects of our physiology, and is often subdivided into two branches: **parasympathetic (deactivating)** and **sympathetic (activating)**.

Parasympathetic stimulation reflects inputs from internal organs, such as the need to digest after eating a meal, and causes a decrease in heart rate[3].

Sympathetic activation is a response to stress, exercise, and illness, and causes an increase in heart rate[4].

HRV emerges from the interplay between these two competing branches of the human autonomic nervous system.

In a balanced nervous system, the human heart is constantly receiving "mixed messages" – commands to increase heart rate from the sympathetic nervous system and commands to decreases heart rate from the parasympathetic nervous system. These mixed messages cause the resulting heart rate to be in a constant state of fluctuation.

Interpretation of HRV

When HRV is high, it is a sign that the body is highly responsive to both sets of inputs, and therefore, **highly capable of adapting to changing environmental conditions**.

When HRV is low, one branch of the autonomic nervous system is sending stronger inputs to the heart than the other.

Digesting vs. Becoming Lunch

One-sided dominance from the nervous system's competing branches is not always a bad thing. Suppose one day while eating lunch, you are faced with a "fight or flight" scenario, like the appearance of a hungry tiger. In this moment, you want your body to focus only on signals from your sympathetic nervous system (which is rapidly sending signals to divert

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[1] Garet et al., 2010
[2] Stauss, 2003
[3] Acharya et al., 2006
[4] Aubert et al., 2003

resources to your legs and avoid becoming this tiger's lunch) and to ignore signals from your parasympathetic nervous system (which is trying to divert resources away from your legs and towards your digestive system to process your own lunch).

In the absence of an immediate threat, however, there is no advantage to favoring one branch's inputs over the other.

Understanding HRV and Athlete Performance

HRV is an individualized measurement. The highest attainable HRV for an athlete is determined by their individual level of fitness[5], age, gender, genetics, health, and environmental conditions like temperature and elevation. Therefore, it is particularly meaningful to consider an athlete's HRV today in the context of recent training history and it is of lesser value to compare HRV between different athletes.

Many factors (besides the immediate threat of a hungry tiger) can temporarily tip the nervous system's sympathetic/parasympathetic balance and reduce HRV.

These include **pain, psychological stress[6], illness, fatigue, and hydration**[7].

Overtraining: A Leading Cause of Injury Risk

A recent series of studies in elite athletes[8,9] has shown that HRV data can be a useful indicator of over-training, a condition defined by persistent decreases in athletic performance despite relative training inactivity[10].

It was just recently that exercise physiologists discovered the connection between baseline HRV levels prior to training and the correlation with improved athletic performance[11]. These findings have made HRV a marker of increasing interest for athletes, coaches, and trainers.

Feeling the Need For Speed?

One key study found that training when HRV levels are at baseline or above results in significantly higher improvements in maximum running velocity than does training according to a pre-planned schedule[12].

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[5] Furlan et al., 1993
[6] Hjortskov et al., 2004
[7] Fogt et al., 2009
[8] Plews et al., 2012
[9] Plews et al., 2013
[10] Robinson, 2003
[11] Vesterinen et al., 2013
[12] Kiviniemi et al., 2007

More Objective Data = Better Coaching

Many wearable technologies have emerged that provide real-time objective measure of the athlete output during training. For the most part, these devices are using some subset of heart rate, accelerometery, and GPS data to measure training load and cardiovascular exertion.

What these devices lack, however, is a context in which to evaluate the appropriateness of a given result. HRV is able to provide that context by providing the strength, conditioning, and performance staff with a validated indication of athlete exercise readiness. Using this data, they should be able to modify an athlete's practice participation and thereby reduce their risk of injury.

Is HRV Just A Fad?

HRV is far from new. In fact, HRV was first documented in 1733, when Reverend Stephen Hales noted that the human pulse appeared to vary with respiration rate[13]. However, HRV wasn't quantified until the advent of the ECG in 1895, and was not popular until the introduction of digital signal processing in the 1960s[14]. In 1965, one study found that fetal distress was preceded by alterations in HRV before alterations in the heart rate itself were observed[15]. After this discovery, HRV quickly became a popular research subject and widely used diagnostic tool.

HRV's Medical Viability

Since the 1960s, HRV has been used as a diagnostic and predictive tool in the medical field. Physicians have used HRV in wide-ranging applications from detection of autonomic neuropathy in diabetic patients[16], in predicting mortality after a heart attack[17], and also to predict the likelihood of post-transplant organ rejection[18].

Measurement Made Simple

Combining scientifically accurate technology with an athlete managed, simple-use model, WHOOP makes HRV information accessible, user-friendly, and easy to understand. WHOOP's information-dense athlete portal is providing wide-ranging value for increasing the safety and effectiveness of training.

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[13] Hales, 1733
[14] Billman, G 2011
[15] Hon and Lee, 1965
[16] Ewing et al., 1985
[17] Kleiger et al., 1987
[18] Task Force of the European Society of Cardiology, 1996

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