AUTONOMIC NERVOUS SYSTEM AND HEART RATE VARIABILITY

Introduction

The autonomic nervous system regulates, among other things, the functions of the vascular system. The regulation is fast and involuntary. The effects can be seen within a few seconds, mainly as various autonomic reactions via the functions of heart rate, smooth muscle tissue and different glands.

The methods that measure autonomic nervous system functions are essentially based on studying the autonomic control of blood circulation. For example, information about different states of the human body can be obtained by measuring heart rate and heart rate variability.

Autonomic nervous system

The autonomic nervous system is divided into sympathetic and parasympathetic nervous systems (Figure 1). Sympathetic and parasympathetic nerve cords start from the central nervous system and lead to different target organs all around the human body. Sympathetic and parasympathetic divisions typically function simultaneously in opposition to each other. The sympathetic division prepares the body to fight by accelerating bodily functions, and is associated e.g. with stress. The parasympathetic division is primarily involved in relaxation, preparing the body to rest and recover.

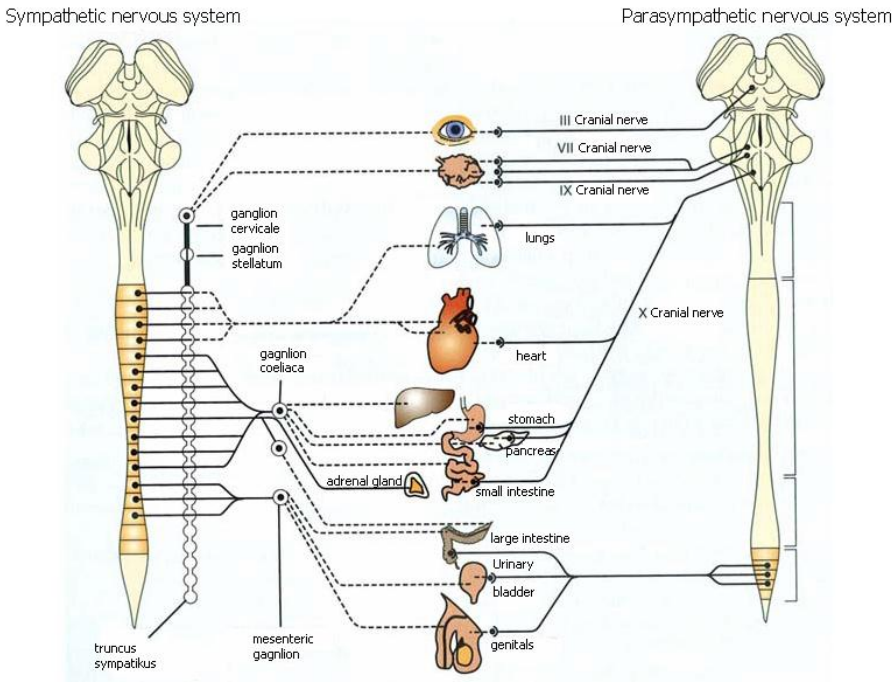

Figure 1: Autonomic nervous system is divided to two functional branches (Source: Sovijärvi, A. et al. 2003)

Sympathetic nervous system

Sympathetic nervous system activity is related to situations where metabolic exertion is needed, for example physical activity or mental / physical exertion at work (Figure 5).Sympathetic activity also increases due to some external disturbance or fear. A classic example about the activation of the sympathetic division is the “fight or flight” –reaction (a situation where life is threatened by some external disturbance): heart rate, blood pressure and adrenal gland hormone excretion are increased, blood flow is directed away from internal organs to the skeletal muscle, and pupils are dilated. All these changes aim for the individual to be able to cope with the physical stress situation in the best way possible. In today’s society, many everyday challenges and stress factors are mental, but also in these cases, the body reacts by increasing its activity. If elevated sympathetic activity is long lasting, there is a danger of developing long-term stress and related illnesses, such as high blood pressure. Over-activity of the sympathetic nervous system can be balanced with moderate physical activity and relaxation exercises.

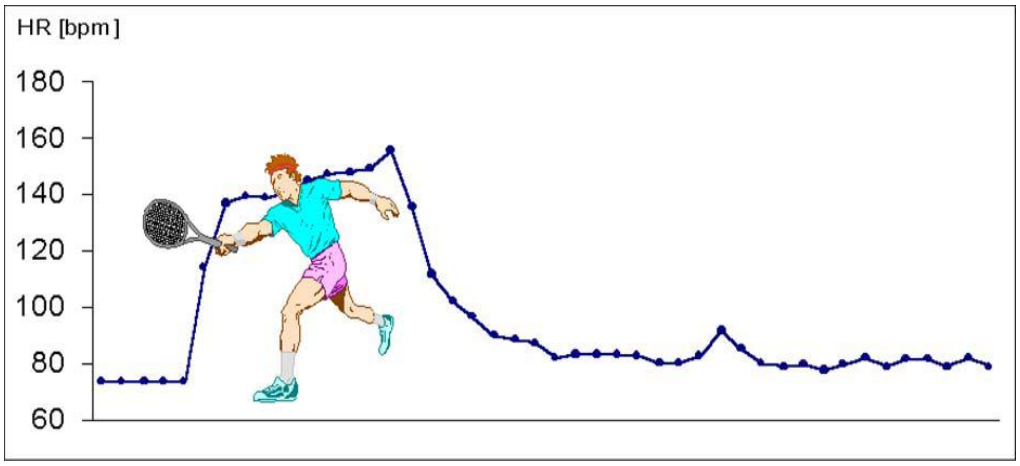

Figure 2: Sympathetic nervous system activity is related to situations where metabolic exertion is needed.

Parasympathetic nervous system

Traditionally, the parasympathetic division of the nervous system has been associated with rest, growth and increased resources. Generally, parasympathetic activation causes opposite effects in the target organs than sympathetic activation; an increase in parasympathetic activity constricts the pupils, decreases the heart rate and intensifies digestion. Parasympathetic regulation also quickly changes the psychophysical mode of the human body. Activity changes in the vagus nerve are related to fast adaptation to inner and outer stimuli. The vagus nerve is the 10th cranial nerve and the most important parasympathetic nerve.

Heart rate variability

Heart rate variability (HRV) refers to beat-to-beat fluctuations in heart rate. Under resting conditions, the ECG of healthy individuals shows periodic variation in R-R intervals. This rhythmic fluctuation is caused by respiration and is known as respiratory sinus arrhythmia (RSA): Heart rate increases during inspiration and decreases during expiration.

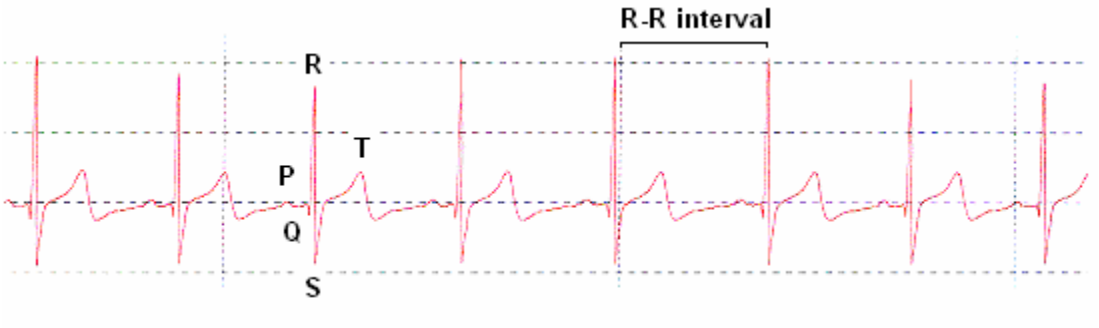

Figure 3: Typical ECG recording revealing the waveform of one single heart beat marked with the different phases (P, Q, R, S and T). R-R interval is the time difference between two consecutive heartbeats.

The rhythm of the heart is controlled by the cardiac sinoatrial node located in the heart. The sinoatrial node receives nerve impulses from the autonomic nervous system, including both sympathetic and parasympathetic branches. This is why the outcome of the interrelationship between the sympathetic and parasympathetic nervous system can be “read” from HRV. Generally, increased HRV is linked to good health and decreased stress. By measuring HRV, the human body can be monitored much more efficiently and accurately than by just measuring traditional heart rate.

Time and frequency domain analyses

Heart rate variability can be analyzed by both time and frequency domain analysis methods. There are also numerous other mathematical methods, but these two types are the most used for HRV analysis.

Time domain measures include:

- SDRRI (standard deviation of RR interval)
- RMSSD (mean squared differences of successive RR intervals)

Frequency domain analysis provides information on how HRV variation distributes as a function of frequency. Frequency domain analysis is usually divided into three frequency bands:

- HF, high-frequency 0.15-0.40 Hz
- LF, low frequency 0.04-0.15 Hz

- VLF, very low frequency 0-0.04 Hz

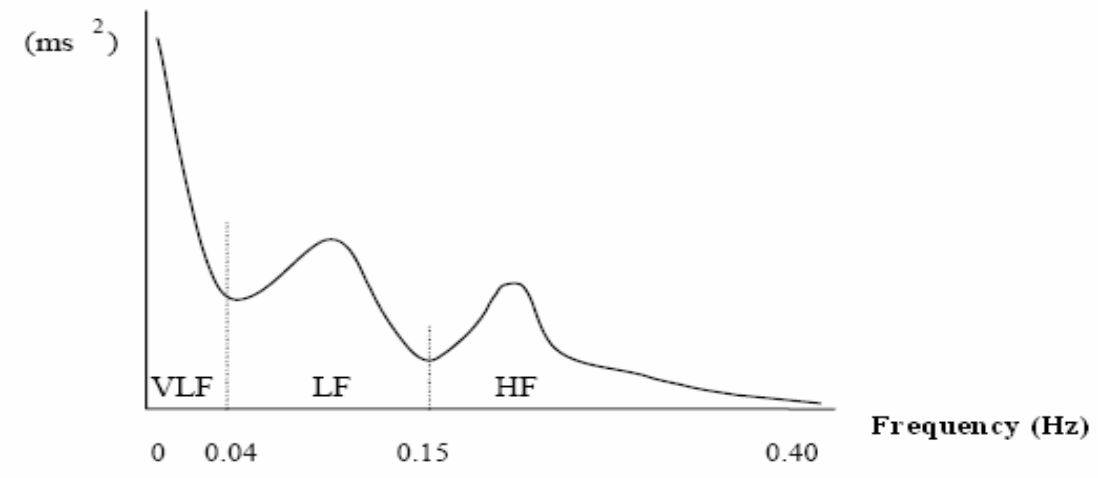

Figure 4: Example of frequency domain analysis of HRV.

Because of the characteristics of nerve receptors, parasympathetic activity usually controls the heartbeat in the range of 0-0.50 Hz and sympathetic activity below 0.10 Hz.

Factors that affect heart rate variability

The factors that affect heart rate and HRV are individual; however, some individual differences are associated with age and aerobic fitness. Resting heart rate increases and HRV decreases with age; the decrease in HRV continues through life. Resting heart rate drops with improved physical fitness, and the changes in heart rate during rest and during exercise depend on the amount of circulating hormones and sympathetic and parasympathetic influence on the sinus node.

Many illnesses related to aging and stress, for example high blood pressure, diabetes and heart failure are associated with reduced HRV. Stress has both acute and more chronic effects on HRV. Numerous studies have shown that negative emotions, such as hate, anxiety, sadness and daily worries reduce HRV. On the contrary, some studies show that positive emotions, such as joy, gratefulness and love increase HRV.

Literature

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