COACH'S HANDBOOK

WINDOWS OF TRAINABILITY™

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TABLE OF CONTENTS

ABBREVIATIONS

Bpm	Beats per minute
CNS	Central Nervous System
DC	Direct Potential of the Brain
ECG	Electrocardiogram
FTIIa	Fast twitch muscle fiber (type IIa, red). Mainly uses aerobic sources of energy supply, but can also draw from anaerobic sources. Resistant to fatigue.
FTIIb	Fast twitch muscle fiber (type IIb, white). Mainly uses anaerobic sources of energy supply. Fatigues very quickly.
HR	Heart Rate (measured in beats per minute)
HRAnT	Heart rate at Anaerobic Threshold
Min	Minutes
mV	Millivolt
RHR	Resting Heart Rate
Sec	Seconds
STMF	Slow twitch muscle fiber (type I, red). Mainly uses aerobic sources of energy supply. Highly resistant to fatigue.

INTRODUCTION

Windows of Trainability™ represents an innovative approach to athlete preparation, one that can be easily integrated into any system of training without imposing radical changes on a coach's existing methodology. Omegawave's approach centers on the concept that the *amount* of the load should not be the primary focus of the training process, but rather *the timing of when* the load is applied.

Synthesizing the extensive experience of leading coaches with multi-disciplinary scientific knowledge and research, Omegawave incorporated the **Windows of Trainability™** approach into the *Coach* product in order to better analyze and predict how an athlete's body adapts to training stimuli.

Utilizing the **Windows of Trainability™** approach will allow for the optimization of the athlete's training process by addressing and providing comprehensive answers to the fundamental dilemmas of coaching:

- Is the athlete ready for another workout, and at what volume and intensity?
- Which physical qualities – endurance, speed & power, strength, or coordination & skill – should be developed to produce the greatest training?
- How can the training process be optimized to achieve the best results in the shortest period of time and with the least amount of physiological cost?

WINDOWS OF TRAINABILITY™: METHODOLOGY

ATHLETES OR THE TRAINING PROCESS – WHICH SHOULD BE THE FOCUS?

The main challenge facing coaches and athletes today is managing the training process in a way that produces **maximum performance results** while **avoiding negative effects**. As we know, mismanagement of the athlete preparation process (p. 6) can lead to overtraining (p. 12), injury, and decreased results. On the other hand, correct and effective management permits the athlete to reach **maximal results** in **minimal time**, while avoiding injury, maintaining good health, and prolonging their career.

Currently, there are several popular approaches to managing athlete preparation (periodization, block system, etc.). However, these approaches have a number of limitations, mainly the excessive focus placed on the *training process* and not on the athlete's current **functional state** (p. 8): this despite the fact that it is the *athlete* that will display the results of training (fig. 1A).

Many coaches create long-term training programs and do not alter them regardless of the response of the athlete. They prescribe training loads using empirical means, based on a general knowledge of the body's *possible* reactions, without an objective account of the ***individual adaptive abilities*** of the athlete (p. 8). At the same time, the athlete will attempt to execute a planned training load – regardless of their functional state – potentially risking harm to their health. This constant over-loading and over-training has been known to contribute to the amount of disease and injury in sport, as well as the early termination of competitive careers.

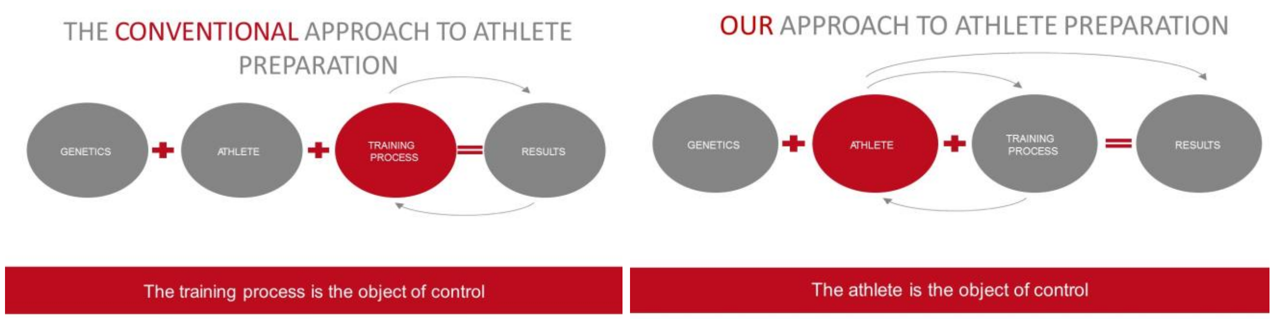


Figure 1. Traditional approach (A) and our approach (B) to athlete preparation.

With the aim of improving the process of athlete preparation in the field of competitive sport, we have created a new approach – **Windows of Trainability™**. To successfully implement this approach, we have also created the *Coach* product – a portable, non-invasive technological solution that provides comprehensive biological feedback on the athlete's current functional state.

WINDOWS OF TRAINABILITY™

Windows of Trainability™ – an athlete-focused approach to the training process that identifies the most effective time frame ("window") for the application of *new* loads **based on frequent analysis and monitoring of the athlete's physiological adaptations to previous loads**.

In contrast to the previously mentioned traditional approaches, **Windows of Trainability™** places the focus on the *athlete* as the object of control, as opposed to the training process itself (fig. 1B). The role of the coach is to manipulate the state of the athlete's functional system by means of the training process (which is used merely as an instrument to achieve a set of goals).

Our approach to athlete preparation is built on the following principles:

1. Comprehensive analysis of a variety of **environmental factors** influencing the athlete (training and non-training related)
2. Frequent monitoring of individual adaptations to these influences
3. Determining the most suitable time for applying various ***types*** of loads, their ***volumes*** and ***intensities*** (p. 11)
4. Formation of a sport-specific **functional system** and adaptations that provide the highest level of ***preparedness*** (p. 6)

Implementing these principles will lead to the **individualization** and **optimization** of the training process.

THE RELATIONSHIP BETWEEN SPORT MASTERY AND PERFORMANCE RESULTS

Sport Mastery – the athlete's ability to realize their highest level of physical, technical, tactical, psychological and intellectual preparedness on demand and under any condition (i.e. in training and competition, during a high state of high psychological stress).

Performance results depend largely on the level of individual sport mastery. During the process of long-term preparation, the goal is for the athlete to achieve the highest level of sport mastery.

However, before they can accomplish this, athletes require a certain level of **preparedness**. Therefore, the main task of the training process is to create the conditions that allow the athlete to achieve the highest level of sport-specific preparedness (fig. 2).

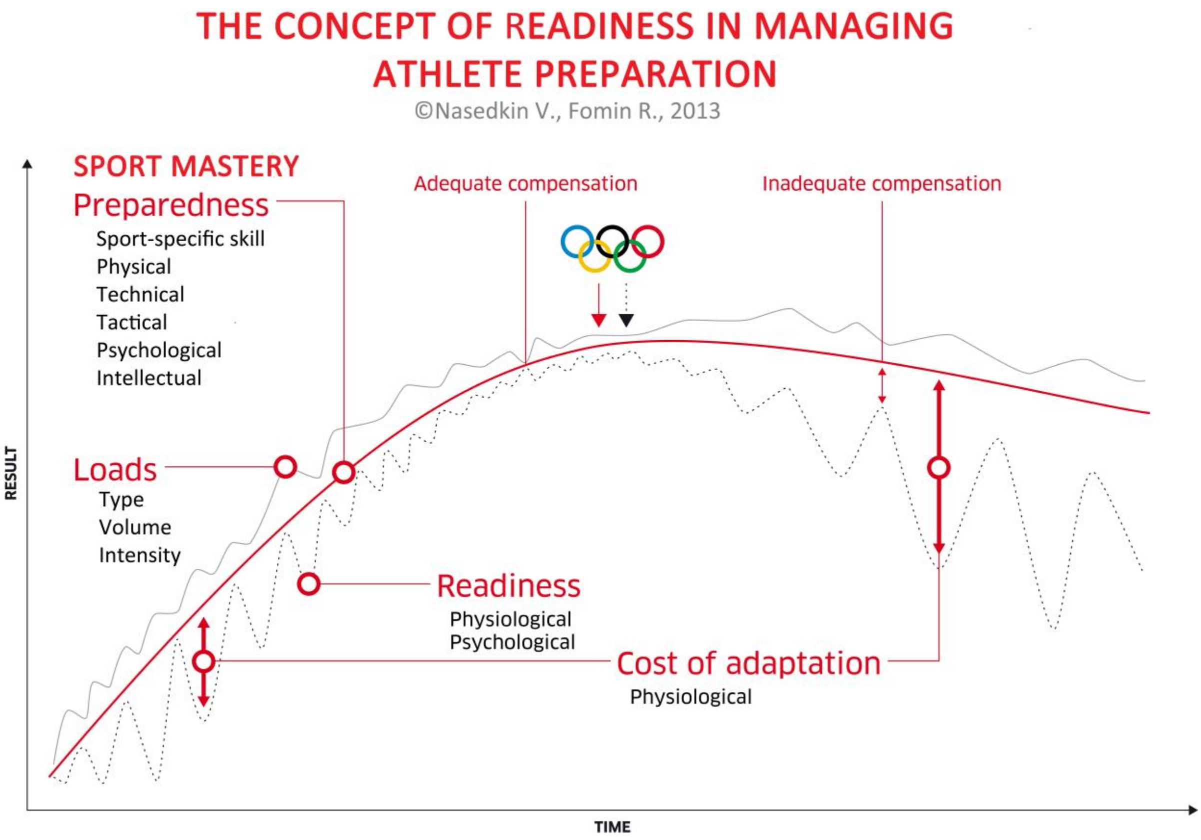


Figure 2. The main components of athlete preparation involved in achieving a desired result.

PREPARATION AND PREPAREDNESS

Preparation – the process of managing all the factors that influence the athlete, ensuring the continuous growth of athletic achievements and results.

Preparedness **–** the multi-faceted, cumulative state of an athlete, composed of a specific developmental level of the following components:

Sport-specific skill – a complex and result-driven pattern of sport-specific behavior and action that is highly automated and requires minimal conscious involvement. Skill is developed through a prolonged process involving multiple repetitions of behavior and action.

Physical – a particular developmental level of sport-specific physical qualities (strength, endurance, speed-power, coordination, flexibility) and the ability to realize these qualities during competition.

Technical – a particular developmental level of sport-specific sequences of movements, consisting of techniques and motor skill(s) that allow the most effective solution for specific motor tasks.

Tactical – a particular developmental level of understanding individual or group tactical challenges in specific training or competition environments.

Psychological – a particular developmental level of mental qualities and functions that allow successful achievement of performance results.

Intellectual – a particular developmental level of the ability to utilize all areas of knowledge to achieve the desired result.

The level of ***sport-specific preparedness*** is characterized by the athlete's ability to comprehensively, simultaneously, and successfully implement all components of preparedness in the specific conditions of a particular sport.

However, a high level of preparedness alone is not enough to achieve the desired result. Another component – **Readiness** (fig. 2) – is the factor that determines whether the athlete is able to perform successfully at any given time.

READINESS

Readiness – the current functional state of an athlete that determines the ability to effectively achieve their performance potential.

EXAMPLE

In preliminary tests Athlete A demonstrates a higher level of preparedness than Athlete B. He is *expected* to repeat this performance in competition. However, in competition Athlete A performs at a lower level than expected and loses to Athlete B, who performs better than expected.

Question:

Why did Athlete A, having shown a higher level of preparedness, lose to Athlete B?

Answer:

Before the competition, Athlete A slept poorly, resulting in a low level of Readiness. Therefore, he displayed a lower level of preparedness during competition, realizing only 70% of his potential.

In contrast, Athlete B slept well, resulting in a high level of Readiness. He displayed a higher level of preparedness during competition, realizing 90% of his potential – allowing him to win.

This example demonstrates that quantifying and analyzing an athlete's Readiness before training and competition is a key factor in achieving the desired result. Therefore, it is critical to utilize an instrument that allows for frequent physiological monitoring of Readiness, and delivers this information in a timely manner – thereby removing guesswork or intuition from the training process.

However, even with this instrument and information about the athlete's Readiness, all facets of constructing a successful training process still need to be decided upon (i.e. what, how, how much, and when to train).

It is not enough to know the *definitions* for sport mastery, preparedness and Readiness. It is also necessary to understand how to *apply* these physiological principles in the construction of the training process. Specifically, how can results be obtained in the shortest amount of time with minimal costs of adaptation? As the body obeys the laws of biology, which biological changes need to be created in order to achieve the desired results? The answers lie in understanding how the body forms a sport-specific functional system.

FUNCTIONAL SYSTEM: THE BASICS

The main factor influencing the preparation process is training load – stimuli causing stress on the body. In response to stimuli, the body tries to adapt and to gradually reduce the cost of adaptation to subsequent loads.

Adaptation – the process of adjusting to training-related and non-training-related changes in the environment.

If loading is regularly repeated, the body begins to form a specific functional system of adaptation to this particular type of activity. This occurs through adaptational restructuring, which aims to be as effective as possible in its consumption and utilization of energy resources while decreasing the cost it pays for the process. The creation of this specific functional system is determined by its usefulness towards achieving a final goal.

Functional System – a dynamic, self-regulating structure of biological components that work in unison to achieve a useful adaptive result for the athlete.

Biological systems (e.g. cardiac, respiratory or nervous systems) do not act in isolation, as taught in classic anatomy and physiology. A functional system is a complex structure that recruits and binds together individual systems and organs to act as a single mechanism. The only criteria for inclusion or exclusion of any biological component (e.g. nervous or muscular systems) in a functional system is its usefulness for achieving the final goal.

The creation of a sport-specific functional system allows the athlete to reach higher levels of preparedness and sport mastery with a minimal cost of adaptation. However, in order to create a useful sport-specific functional system it is important to first decide which means and methods to use.

MEANS AND METHODS: WHAT AND HOW TO TRAIN?

Basic ***means*** of preparing athletes include a ***variety of physical exercises*** which help to form the sport-specific functional system and create useful adaptations. Selection and implementation of these exercises depends on the particular sport and the exercises' role in the development of the various components of preparedness.

For instance, to increase the level of physical preparedness one may only implement physical exercises aimed at developing one or another physical quality – strength, endurance, etc. However, to increase technical preparedness, physical exercises alone may not be enough. Therefore, a combination of physical, psychological and intellectual exercises should be employed.

Methods of preparation refer to the *manner* in which exercises are performed in the preparation process. The most common methods are continuous exertion, intervals, games, circuit training and competition.

The next step is to understand how to apply the training load using the appropriate means and methods.

TRAINING LOAD: TOO MUCH OR NOT ENOUGH?

Training load – a specific amount of training stimulus applied to the athlete in order to provoke crucial adaptations in the sport-specific functional system.

Training load is the primary factor that produces adaptations in the individual organs and tissues of the functional system, as well as adaptational restructuring in the functional system as a whole. The quality and quantity of this adaptational restructuring will determine the effectiveness of the training process, which in turn determines the athlete's ability to achieve desired results.

The impact of training load can be categorized in the following ways, depending on the proportion of skeletal muscle involved during exertion:

> ***Local*** – loads are performed by less than 25% of skeletal muscle and cause no significant biochemical changes in the body. For example, snapping one's fingers.
>
> ***Regional*** – loads are performed by one or more muscle groups (approximately 50% of skeletal muscle) and cause somewhat significant biochemical changes in the body. For example, executing an underhand serve in volleyball, or performing an element of gymnastics.
>
> ***Global*** – loads are performed by more than 75% of skeletal muscle and cause significant biochemical changes in the body. For example, jogging, swimming, or cross-country skiing.

Training loads can be broken-down into three categories: ***type***, ***volume***, and ***intensity***.

> ***Type*** – specific exercises implemented to develop a physical quality (i.e. endurance, speed & power, strength, coordination & skill).
>
> ***Volume*** – the amount of load applied during a defined period of time (e.g. the duration and distance covered during a run).
>
> ***Intensity*** – the impact of the stimulus on the body during a defined period of time (e.g. pace of the game, running velocity, energy expenditure per minute).

An important component of training load is the power required to produce the work. Relative to exertion, power and duration are inversely related – the higher the power output required, the less time that output can be maintained. Also, the higher the power output, the greater the biochemical changes that will result in the body.

The work performed during cyclical activities can be categorized into eight ***power zones:***

Anaerobic zone

> ***Maximal*** – not more than 15-20 sec
>
> ***Submaximal*** – 25-40 sec
>
> ***High*** – from 45-120 sec

Aerobic zone

Maximal – 3-10 min

Submaximal – 10-30 min

High – 30-80 min

Moderate – 80-120 min

Low – more than 2 hours

The type of training load can be adjusted by volume or intensity, or both simultaneously. The training load should be individualized depending on the sport-specific functional system targeted for development. The load for a particular athlete should be just sufficient to cause a useful adaptive response and a positive training effect (fig. 3A) – no more, no less.

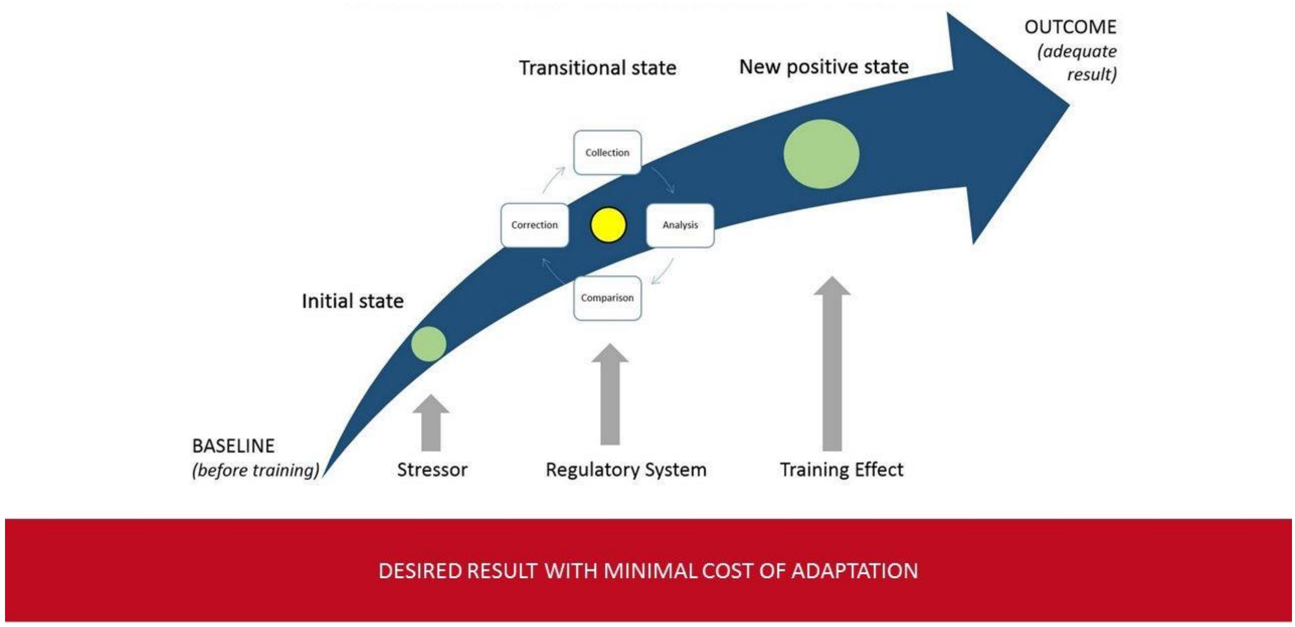


Figure 3A. How a desired training effect is produced through the Regulatory System.

Prescribing an excessive load (overloading) will produce adaptations that lead to negative and undesired consequences, i.e. a decrease in work capacity, overtraining, illness or injury (fig. 3B red arrow). When the cost of the adaptations is too high, the result is an unsuccessful functional system.

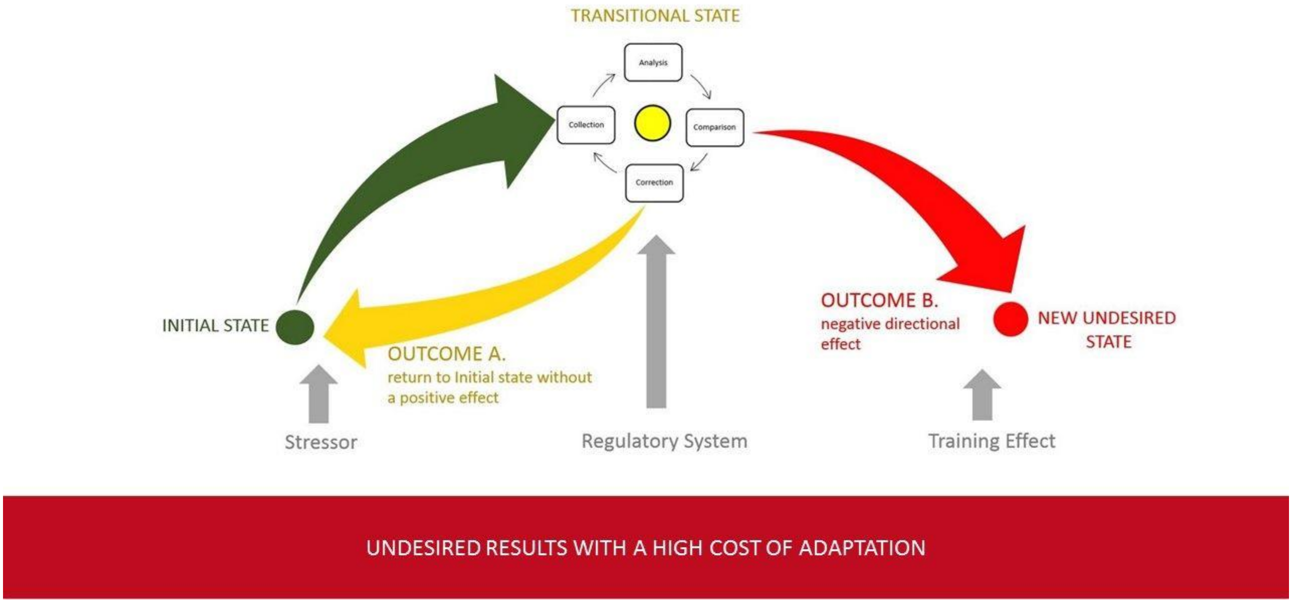


Figure 3B. How an undesired training effect is produced through the Regulatory System.

An *insufficient* load (fig. 3B, yellow arrow), on the other hand, produces *no* training effect, and the athlete is unable to reach a higher level of preparedness. The task of creating a sport-specific functional system was not achieved due to the lack of sufficient stimulation.

Consequently, it is crucial to know not only the *type* of load to prescribe for the day's training, but also to correctly select the *volume* and *intensity***.** Strict adherence to a pre-set plan will not result in the desired outcome. The magnitude (volume and intensity) and type of training load can be changed daily according to the individual physiological reactions of the body and the current stage of development of the sport-specific functional system.

However, it will be difficult – if not impossible – to select the proper training load without obtaining objective feedback on the adaptive responses of the athlete.

FATIGUE AND RECOVERY: TWO PARTS OF ONE PROCESS

Fatigue and recovery are two components of a single, complicated adaptation process brought on as a result of training loads. These components also occur as a natural part of the formation of a functional system. The goal is to create conditions that will promote a more symbiotic balance between fatigue and recovery.

***Fatigue* –** a *temporary state* that occurs during intense or prolonged work that leads to a decrease in the effectiveness of the work.

Recovery – a *process* that occurs as a reaction to fatigue. This process should always lead to the creation of a new and improved functional state.

Many believe that recovery is simply a return of physiological parameters to the pre-load level. However, if the parameters simply return to their pre-load level, there would be no creation of a newly improved functional state: therefore, there would be no improvement of performance results.

To create a more effective recovery process, it is critical to first identify the physiological component that was affected by fatigue. Only then can specific recovery means and methods be employed successfully.

OVERREACHING AND OVERTRAINING

Overreaching – a *temporary* state of fatigue that occurs in response to high and intense loads, without allowing time for sufficient recovery. Characterized by malaise, sleep disturbance, mood instability and a marked decrease in performance capability.

Overtraining – a *chronic* state of exhaustion. This is a pathological state caused by repeated, prolonged, high intensity, high volume and monotonous loads without allowing time for sufficient recovery. This state is primarily characterized by significant disturbances in the nervous and hormonal systems.

Currently, overreaching and overtraining are a large and widespread problem in sport. In a state of fatigue, the body's ability to adapt to training loads greatly decreases. If the onset of overreaching is identified and the athlete is allowed to recover, performance capability will return to normal levels. However, if immediate action is not taken and the athlete continues training without sufficient time for recovery, adaptation processes will begin to fail, leading to an unwanted state of *overtraining*. Athletes in an over-trained state cannot compete successfully and produce their best results, while also being at risk for illness and injury.

To promptly identify and remedy a state of overreaching or overtraining, it is not only necessary to recognize the signs of these conditions, but their causes as well.

The main signs of overreaching and overtraining are an increased susceptibility to fatigue, a decreased physical work capacity and a reduced recovery rate. Despite continued training, sport-specific results decline. This is a signal from the body that it can no longer adapt to the prescribed training load and the athlete needs a change in the training load or immediate rest.

Initial signs of overreaching and overtraining are characterized by a predominance of excitatory processes:

- slow heart rate recovery in response to training load
- abnormally high resting heart rate
- high arterial blood pressure
- palpitations
- nervousness and emotional instability
- restlessness and poor sleep quality
- decreased attention span
- increased anxiety and unwarranted fears
- excessive sweating during exertion
- decreased interest in training
- decreased appetite and weight

If the initial signals are ignored and the athlete continues intense training, subsequent signs of overreaching and overtraining emerge. These are characterized by a predominance of inhibitory processes:

- reduced rate of recovery
- abnormally low resting heart rate

- low blood pressure
- depression
- increased fatigue
- rapid onset of fatigue during exertion
- drowsiness and lethargy
- hypoglycemia
- reduced immune system response

If immediate steps are not taken to adjust the training process, the onset of even more severe disorders will follow.

Currently, the most important causes of overreaching and overtraining fall into the following categories:

METHODOLOGICAL

- Imbalance between load and rest: high volume or high intensity loads that exceed the capacity of the body to recover
- Lack of, or incorrect, periodization of the training process
- Monotony, dullness, excessive duration and repetition of training
- Lack of individualization of the training process
- Absence or neglect of recovery activities
- Excessive amount of competitions

PHYSIOLOGICAL

- Insufficient or poor quality sleep
- Unbalanced and irregular meals
- Reduced resistance to physical and mental stress
- Predisposition of the individual to adapt to a given training load

PSYCHOLOGICAL AND SOCIOCULTURAL

- Excessive psychological load and chronic stress at work or home
- Unrealistic goals and aims
- Strong fear of failure
- Conflict with a coach or other athletes
- Disorganized lifestyle

MEDICAL

- Diseases (chronic, infection, etc.)
- Allergic reactions
- Inadequate recovery from past injuries

ENVIRONMENTAL

- Changes in time zone and climate
- High altitude training

- Poor ecological conditions

The conventional means of preventing overreaching and overtraining include a balance of load and recovery, proper sleep and diet, active rest, massage, sauna, pharmacology, etc. These means are limited because their effect cannot be frequently measured; therefore, this information cannot be used to manage the training process.

Overreaching and overtraining can be more efficiently prevented by frequently monitoring the functional state of the athlete with objective scientific methods before and after the training load is applied. Since each athlete will display the signs of overreaching and overtraining in a different fashion, it is essential to implement a customized approach to the evaluation process.

Fatigue is not necessarily an undesired consequence of training – it is the *magnitude* of fatigue that is critical. On the one hand, the more that progressively greater magnitudes of training load are applied, the better prepared the athlete will become. On the other hand, if the level of fatigue is not managed, an overdose may be applied, thereby causing the athlete to train while tired and eventually leading to a decline in results. Consequently, understanding the interplay between fatigue and recovery is the key to attaining high performance results.

Caution: recovery protocols must be employed correctly, as recovery activities themselves may be an additional burden on the body, possibly increasing the level of fatigue.

TRAINABILITY AND TRAINED-STATE: SIMILAR BUT DIFFERENT

How does the Windows of Trainability™ approach view the concepts of trainability and trained-state?

Trainability – the ability to receive training loads (input) and effectively adapt to them (process), thereby producing a positive training effect (output). Increasing trainability leads to an improved capacity to reduce the negative effects of training-related and non-training-related changes in the environment and decreases the costs of adaptation.

Trained-State – a state characterized by accumulated long-term adaptations that have resulted in a higher level of preparedness.

In response to the constant stressors of a training load, the body adapts by adjusting its functionality to minimize the physiological changes that occur in response to the load. This process results in the ability to pay a smaller physiological cost for subsequent (though similar) loads. Therefore, the body becomes more effective in adapting to training and producing positive results.

It is clear that in order to continuously enhance the athlete's trained-state, it is necessary to progressively increase the training load. However, blindly following an approach dictated by "the more (load) the better" does not produce the best results.

The Windows of Trainability™ approach offers a more evolved solution. The *amount* of load is not the most important parameter to consider, but rather *when* the body is ready to receive and adapt to another load. During periods when adaptation processes are complete, the body is most ready to benefit from new loads. The opposite is also true – during periods when adaptation processes are incomplete, the body is not able to benefit from new loads. We termed these periods of time 'windows of trainability'.

> **Window of Trainability** – *a period of time*, determined by the current functional state of the athlete, during which a decision needs to be made whether or not to apply a particular training load that is designed to lead to useful adaptations and improve athletic performance.
>
> **Open Window of Trainability** – *a period of time* when the application of a particular training load will lead to positive adaptations, and thus improved athletic performance.
>
> **Closed Window of Trainability** – *a period of time* when the body is in a state of imbalance and reduced functioning, reflecting a lack of Readiness for particular training loads.

EXAMPLE

All things being equal, Athlete A has a ***fully open window of trainability*** for developing strength (indicated by a reading in the green zone on the Omegawave *Coach* application). In training, he performs exercises with maximal loads and intensities. His body *is able to process* the load and create a positive adaptation, thus improving his performance results.

Athlete B has a ***closed window of trainability*** for developing strength (indicated by a reading in the red zone). However, he is unaware of this and performs the same training as Athlete A with maximal loads and intensities. His body is *not able to process the load* and form useful adaptations because the process of adaptation to previous loads is incomplete. Consequently, not only did he fail to improve his results, but having to compensate for this state of poor Readiness, the physiological cost for Athlete B was higher than for Athlete A.

(Note: An athlete can have an open window of trainability for one quality and a closed window of trainability for another during the same period of time.)

Correct and timely identification of the ***window of trainability*** permits not only the selection of the type, volume and intensity of loading, but also the proper timing of its application.

WINDOWS OF TRAINABILITY™: IMPLEMENTATION

DEVELOPING PHYSICAL QUALITIES

With the goal of better understanding how to implement Windows of Trainability™, we will use the *Coach* product from Omegawave as an example.

Based on a comprehensive analysis of the functional state of the CNS, cardiac and metabolic systems, Omegawave *Coach* identifies when a 'window of trainability' for developing specific physical qualities is open or closed. The technology can be used to determine the ***most favorable time*** and ***preferable condition*** in which to develop primary motor qualities that affect the level of preparedness and sport mastery. These qualities include: ***endurance, speed & power, strength,*** and ***coordination & skill.***

The *Coach* product answers three primary questions important in creating optimal training solutions (fig. 4):

1. Which physical quality ***can be*** developed today, in order to achieve the *maximal* training effect?
   - *Answer: speed & power*
2. Which physical quality *can be* developed today so as to achieve a *limited* training effect?
   - *Answer:* both *endurance* and strength
3. Which physical qualities are *not recommended* to be developed today, so as to not cause a *loss* of training effect?
   - *Answer: coordination & skill*

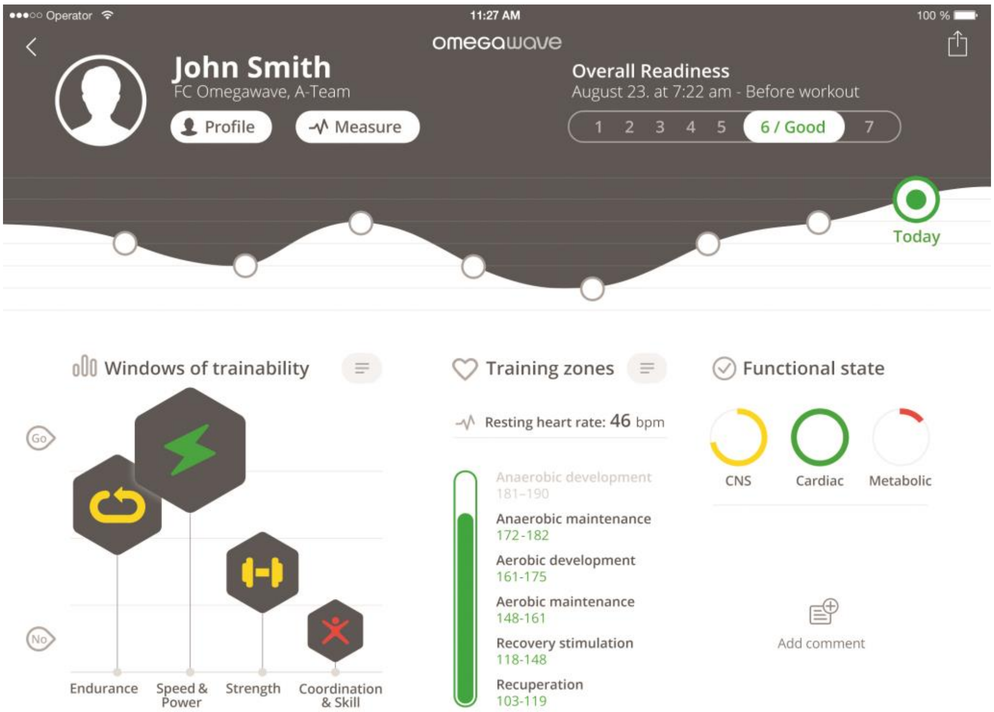


Figure 4. Athlete analysis page of the *Coach* product.

Each measurement is additionally analyzed by the Omegawave Expert System[1] to provide an integrated conclusion (fig. 5), which reflects:

• The Readiness of the athlete for upcoming loads and the development of specific physical qualities

• The recommended magnitude of the training load (volume and intensity)

Implementing these recommendations allows for the formation of necessary adaptations to the sport-specific functional system by appropriately selecting the type, volume, and intensity of the training load.

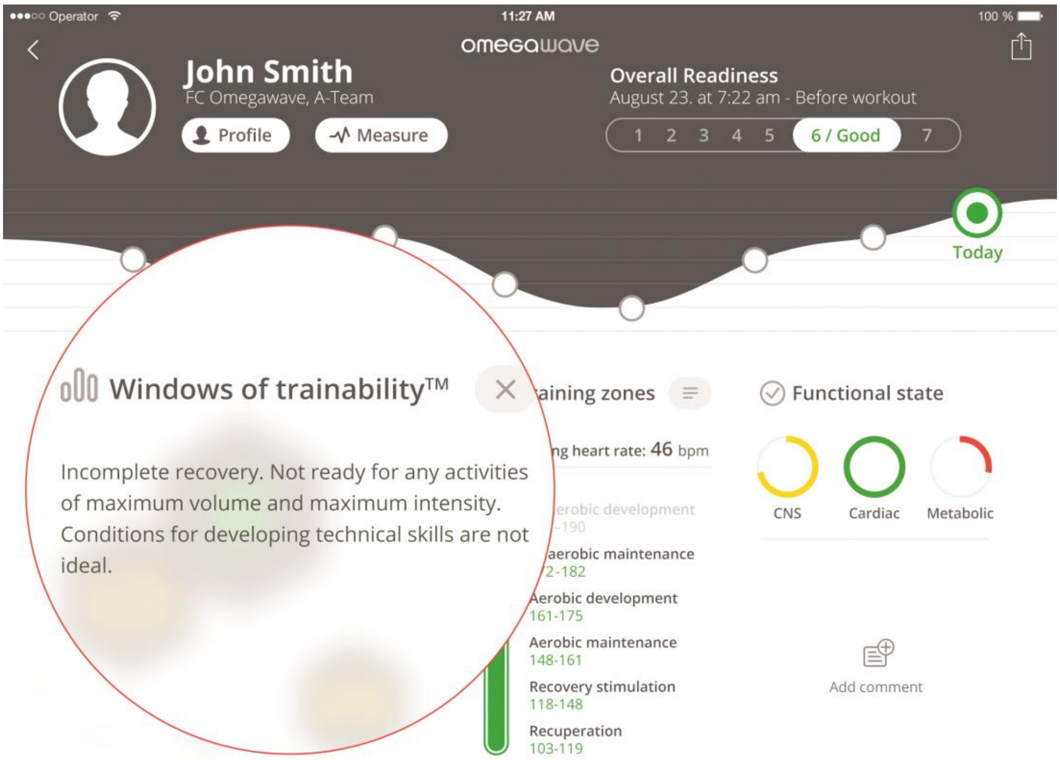


Figure 5. The integrated conclusion provided by the Omegawave *Coach* product.

ENDURANCE

Endurance – the ability of the body to effectively perform prolonged work while resisting fatigue.

To achieve the highest levels of endurance, the training process must not only induce adaptations in individual organs and systems (e.g. cardio-pulmonary system), but more importantly it must induce adaptations within the *sport-specific functional system* as a whole – which is responsible for ensuring that the final result is useful.

Creating positive adaptations in the sport-specific functional system allows the athlete to resist cumulative fatigue and the onset of overreaching, to perform more demanding muscle work, to adapt and compensate for daily training and competition loads of greater intensity and duration, and to realize continuous improvement of results.

Adaptations in the functional system separate amateur athletes from the elite; amateurs have not fully developed these adaptations, whereas elite athletes have.

With respect to the type of adaptations within the functional system, endurance can be separated into two categories – general and specific:

General Endurance – the ability to perform prolonged, non sport-specific work, which indirectly improves the sport-specific functional system and the preparedness of the athlete.

General endurance lays the foundation for the development of sport-specific endurance. During the development of general endurance it is necessary to form general physiological adaptations in organs and systems that are relevant to the sport (e.g. cardiac hypertrophy, increased number of capillaries, etc.). These adaptations must act as a foundation on which to create the subsequent sport-specific adaptations in the functional system.

Sport-Specific Endurance – the ability to perform prolonged, sport-specific work in situations that simulate the competition environment.

This work directly enhances the formation of the sport-specific functional system, sport mastery and preparedness of the athlete. Sport-specific endurance is created by particular adaptations with the aim of continuously improving the sport-specific functional system.

Adaptations Required for Enhanced Endurance

Pulmonary System:

- Enhanced power and effectiveness of external respiration

Cardiovascular System:

- Increased power, effectiveness, and economy of the cardiovascular system
- Increased parasympathetic activity and decreased sympathetic activity within the autonomic nervous system
- Myocardial hypertrophy and an increase of myocardial ventricular volume
- Bradycardia and sinus arrhythmia
- Improved excitation, metabolism, and myocardial regulation
- Increased capillarization
- Improved elasticity of blood vessels
- Increased systolic volume (cardiac output)
- Increased speed and amplitude of cardiac contractions

Muscular System:

- Increased density and quantity of capillaries
- Increased quantity, size and density of mitochondria
- Increased quantity and activity level of oxidative enzymes, hormones and other regulators of oxidative processes
- Increased hemoglobin and myoglobin
- Increased aerobic resynthesis of ATP
- Increased intensive oxidation of fats and reduced intensive oxidation of carbohydrates (the most important energy metabolism adaptation for endurance)
- Increase ratio of oxidative to glycolytic muscle fibers

Hormonal System:

- Increased mass of endocrine glands
- Increased concentration of steroidal hormones in organs and tissues

Possible Methods for Developing Endurance

The most important task in the development of endurance is to increase the athlete's capacity to produce energy and to utilize it economically within a competition environment. The primary means of achieving this include general and specific exercises that are performed under various intensities that target particular pathways of energy metabolism. The three pathways of energy metabolism are:

- ***Anaerobic alactic*** – uses creatine phosphate as a source for re-synthesizing ATP in the *absence* of oxygen.
- ***Anaerobic lactic*** *(glycolytic)* – uses glycogen and glycolysis in order to re-synthesize ATP in the *absence* of oxygen. This results in a by-product of lactate and hydrogen ions.
- ***Aerobic*** – uses carbohydrates and fats as the primary source for the re-synthesis of ATP in the *presence* of oxygen.

In order to improve endurance, the training process needs to progressively develop the *power, capacity,* and *efficiency* of the metabolic pathways.

- ***Power*** – the *highest rate* of energy production within a particular pathway. Indicative of the level of intensity of muscle work.
- ***Capacity*** – the *total amount* of energy that can be produced within a particular pathway. Indicative of the volume of muscle work.
- ***Efficiency*** – the amount of muscle work attained compared to the energy produced. Indicative of the *economy* of muscle work.

There are many methods that can be used to develop the complex and multi-faceted quality of endurance, including:

- ***Interval Training***
- ***Repetition Training***
- ***Fartlek Training***

(*Note: for more details see the next section, Windows of Trainability™ for Heart Rate Training Zones.)*

Windows of Trainability for Endurance

After just a single comprehensive assessment of the functional state and identification of the athlete's Readiness for upcoming loads, the Omegawave *Coach* product determines whether the window of trainability for endurance is open or closed (fig. 6).

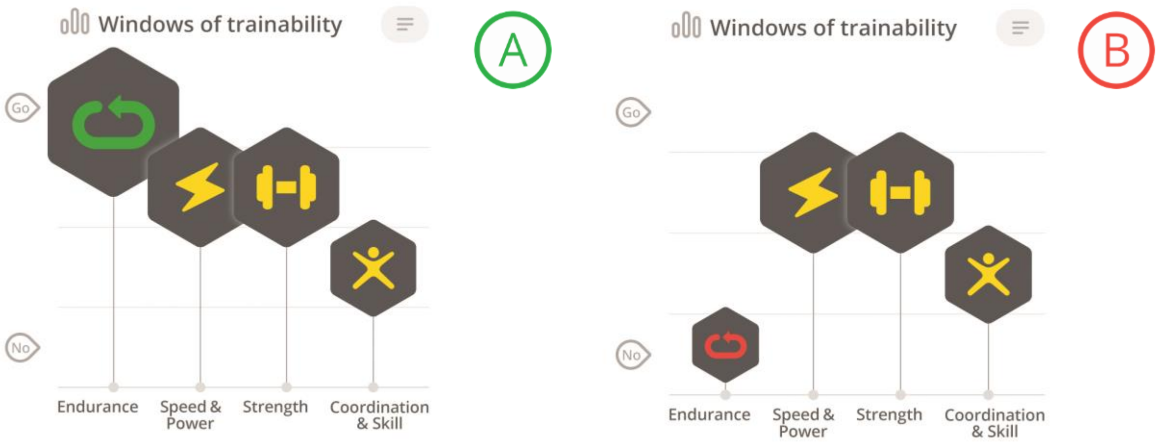


Figure 6. Open (A) and closed (B) windows of trainability for the development of endurance.

When the window of trainability for endurance is *fully open* (fig. 6A), a variety of means and methods can be used to induce critical adaptations within the sport-specific functional system and achieve the maximal training effect.

When the window of trainability for endurance is *partially open* for a limited training effect, the athlete's capability to develop this physical quality is reduced. Caution should be exercised in prescribing a training load.

When the window of trainability for endurance is *closed* (fig. 6B), no attempt should be made to develop endurance at that time. The sport-specific functional system is not ready to form ***new*** adaptations, as it is still in the process of adapting to previous loads. In this situation, the athlete can train to develop other physical qualities, if indicated by their measurements. In doing so, new adaptations will be created in organs and systems in which recovery from previous loads has been completed (for example, the nervous system).

***Speed* – the ability to perform simple and complex movements in the minimal amount of time.**

Speed is primarily dependent on the functional properties of command centers (executive branch) in the central and peripheral nervous system as well as the functional properties of skeletal muscles (administrative branch).

There are **two forms** of speed:

- **Elemental**
  - Speed of simple and complex motor reactions (e.g. reaction to light, sound, etc.)
  - Speed of a single action (e.g. start from the blocks)
  - Frequency of movement (i.e. tempo)
- **Complex**
  - Speed of complex multi-joint actions (e.g. punching, kicking, ball handling)

Critical Adaptations for Improved Speed

In order to create a sport-specific functional system, three types of adaptations are required for the development of speed – neural, muscular, and metabolic.

Neural adaptations:

- Ability to activate maximum amount of motor units in type IIa and type IIb in minimal time
- Increased power of efferent impulses to the motor units
- Increased lability of neural processes
- Improved relationship between processes of inhibition and excitation in different parts of the nervous system
- Improved neuromuscular coordination

Muscular adaptations:

- Increased amount of type IIa and type IIb muscle fibers
- Improved elasticity and flexibility of muscle
- Increased effectiveness of intra-muscular coordination

Metabolic adaptations:

- Improved mobilization and functioning (re-synthesis of creatine phosphate and ATP) of the anaerobic alactic energy system
- Increased power and capacity of the anaerobic alactic energy system

Possible Methods for Developing Speed

The primary means for developing speed are exercises that require quick motor reactions, as well as high velocity and frequency of movement. These exercises should always be placed at the beginning of the training session. During speed development, emphasis should be placed on performing complex multi-joint sport-specific actions.

The main principles for the development of speed are:

- 5-8 repetitions of a selected exercise per session, 6-8 minutes of rest between repetitions
- 2-3 sessions per week
- Maximal or supramaximal intensity
- Exercises must not be performed in a state of fatigue

Primary methods for the development of speed:

- Competition
- Exercises designed to improve spatial and temporal anticipation
- Exercises with increased or decreased resistance

Power – the ability of the body to produce maximal strength in minimal time.

Power is a combination of the function of the nervous system and skeletal muscle. To develop a sport-specific functional system, both neural and muscular adaptations are required.

Neural Adaptation – adaptations created in command structures (brain cells, etc.) and functional processes in the central and peripheral nervous system in response to a particular training load. These adaptations are created based on their usefulness to achieve the desired results, and form the *command center* (executive branch) of a specific functional system that sends signals to muscles through an active *feedback loop* between the *brain* and *spinal cord*.

Muscular Adaptation – structural and functional adaptations in skeletal muscles created in response to a particular training load. These adaptations are created based on their usefulness to achieve the desired results, and form the *administrative branch* of a specific functional system. This branch carries out orders from the command center as to the duration and intensity of the muscle's contraction (fig. 7).

Muscles require specific adaptations in order to successfully respond to the signals of the command center. If these adaptations do not exist, the muscles will be unable to respond accordingly even when the signals are received.

The command center constantly processes information received through the feedback loop about the state of the muscles. Based on this information, it distributes signals to either maintain or correct the athlete's performance, depending on the situation.

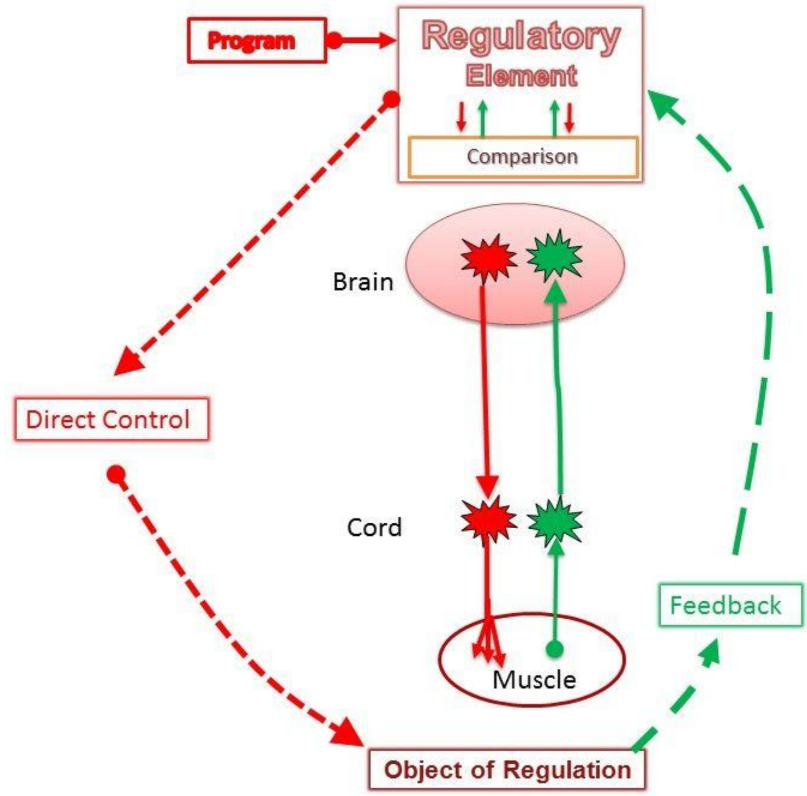


Figure 7. Example of a functional system, critical for the realization of power.

In this way, the executive and administrative branches work as one functional system to manage adaptations. This process of management in the functional system is based on the fact that some elements of the system change their state under the influence of other elements. This process is critical for the whole system to be in an optimal state in the given circumstances.

The challenge is to use various means and methods to influence different components of the sport-specific functional system in order to speed up the processes of adaptation in these components (neural and muscular) and the functional system as a whole. Due to the fact that there are only informational connections between components, the training process should be managed in such a way that these connections contribute to the creation of positive adaptations to energy production in the brain and muscle as well as improved plasticity processes in the functional system.

Critical Adaptations for Increased Power

Neural adaptations:

- Improved ability to recruit a maximal amount of muscle fiber in a minimal amount of time
- Improved innervation of muscles
- Improved inter-muscular coordination

Muscular adaptations:

- Hypertrophy
- Increased mitochondrial density
- Increased muscle excitability
- Increased muscle density
- Increased intramuscular coordination

Possible Methods for Developing Power

- Shock method
- Plyometrics
- Sprint training
- Weightlifting

Windows of Trainability for Speed & Power

Before applying a new training load, it is vital to determine whether prior adaptation processes in the nervous and muscular systems have been completed or not. To this end, the Omegawave *Coach* product indicates whether the athlete has an open or closed window of trainability for the development of speed and power (fig. 8).

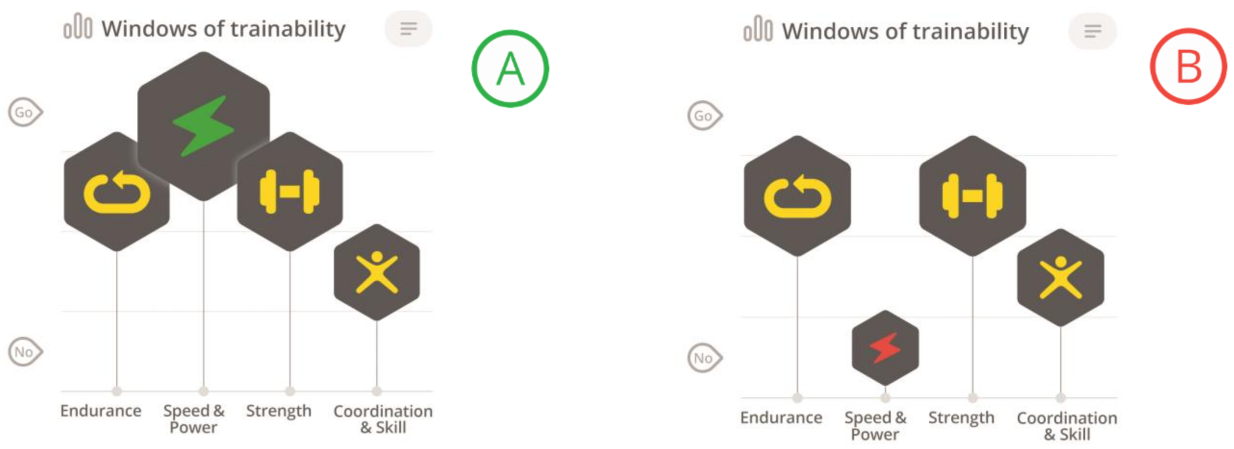


Figure 8. Open (A) and closed (B) windows of trainability for the development of speed & power.

As discussed in the previous section, when the window of trainability is *fully open* (fig. 8A), a variety of means and methods can be used to induce critical adaptations within the sport-specific functional system and achieve the maximal training effect.

When the window of trainability for speed and power is partially open for a limited training effect, the athlete's capability to develop these physical qualities is reduced. Caution should be exercised in prescribing a training load.

When the window of trainability is *closed* (fig. 8B), no attempt should be made to develop speed and power at that time. The sport-specific functional system is not ready to form ***new*** adaptations, as it is still in the process of adapting to previous loads. In this situation, the athlete can train to develop other physical qualities, if indicated by their measurements. In doing so, new adaptations will ensue in organs and systems in which recovery from previous loads has been completed (for example, the nervous system).

STRENGTH

Strength **– the maximal amount of force a muscle or muscle group can generate.**

The definitions of strength and power illustrate their difference – only power has a relationship with time.

In order to display strength, two types of adaptations are critical for the creation of a sport-specific functional system: neural and muscular.

Critical Adaptations for Increased Strength

Neural adaptations:

- Increased amount of active motor units and frequency of their excitation
- Synchronization of motor unit function and increased ability to recruit additional motor units for a task
- Increased innervation of muscle tissue

Muscular adaptations:

- Hypertrophy
- Increased mitochondrial density
- Increased oxidative processes
- Increased muscle excitability
- Increased muscle density

Possible Methods for Developing Strength

The primary objective when selecting exercises for the development of strength should be to manage the creation of adaptations in such a way that they are integrated and organized into a single functional system. The resulting functional system will allow the athlete to improve their sport-specific strength.

Methods for the development of strength can be classified based on the ***type of muscle contraction:***

- ***Isometric*** – the *length* of the muscle does not change.
- ***Isokinetic*** – a constant *rate* of movement.
- ***Isotonic*** – constant muscular *tension* during movement without a full flexion or extension.
- ***Concentric*** – muscle fibers shorten while generating force.
- ***Eccentric*** – muscle fibers lengthens while under tension.

The methods can be further categorized based on the type of ***loading***:

- ***Supramaximal*** – loads above the individual maximal capacity (>100%)
- ***Maximal*** – loads close to the individual maximal capacity (95-100%)
- ***Submaximal*** – loads in the range of 70-95% of maximal capacity
- ***Moderate*** – loads in the range of 40-70% of maximal capacity
- ***Light*** – loads up to 40% of maximal capacity

Windows of Trainability for Strength

As with power, it is vital to determine whether prior adaptation processes in the nervous and muscular systems have been completed before applying a new training load. To this end, the Omegawave *Coach* product indicates whether the athlete has an open or closed window of trainability for the development of strength (fig. 9).

As discussed in the previous sections, when the window of trainability is *fully open* (fig. 9A), a variety of means and methods can be used to induce critical adaptations within the sport-specific functional system and achieve the maximal training effect.

When the window of trainability for strength is *partially open* for a limited training effect, the athlete's capability to develop this physical quality is reduced. Caution should be exercised in prescribing a training load.

When the window of trainability is *closed* (fig. 9B), no attempt should be made to develop strength at that time. This is because the sport-specific functional system is not ready to form ***new*** adaptations, as it is still in the process of adapting to previous loads. In this situation, the athlete can train to develop other physical qualities, if indicated by their measurements. In doing so, new adaptations will ensue in the organs and systems in which recovery from previous loads has been completed (for example, the nervous system).

Figure 9. Open (A) and closed (B) windows of trainability for the development of strength.

COORDINATION & SKILL

***Coordination* – the ability to integrate motor actions into an efficient pattern of movement.**

Coordination includes the perception and analysis of dynamic, temporal and spatial characteristics of the body's movement; conceptualization of how to perform a given task; construction of an appropriate plan of action; and the execution of that plan.

An important factor in coordination is operational control, which consists of the performance of movement, the processing of feedback, and the process of making adjustments. Within operational control, the preciseness of afferent information received from muscle receptors and the quality of its processing in the CNS play a key role.

If the CNS is fatigued, the quality of operational control will be reduced, resulting in poor or inadequate coordination.

In relation to the structures of the sport-specific ***functional system*** and the stages of creation of motor skills, two types of adaptations critical to the development of coordination can be distinguished – neural and muscular.

Critical Adaptations for Improved Coordination

Neural adaptations:

- Improved movement memory (ability to memorize and reproduce movement)
- Increased repertoire of skills
- Increased number of movement patterns in the CNS and the ability to use them under pressure (especially when the CNS did not have sufficient time to process the information)
- Improved transmission of nerve impulses
- Improved function of the various sensory systems (visual, auditory, vestibular system, and somatosensory system)
- Improved postural control

Muscular adaptations:

- Improved inter/intramuscular coordination
- Improved coordination of muscle antagonists and synergists

- Increased rate of activation and relaxation of involved muscles
- Improved voluntary contraction and relaxation

Possible Methods for Developing Coordination

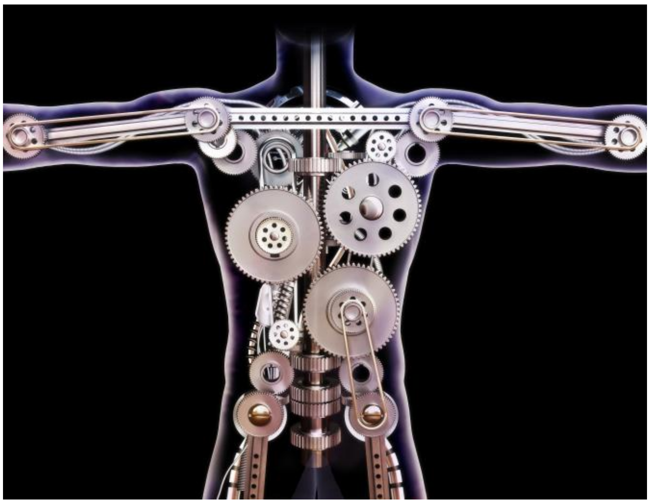
The primary objective when selecting exercises for the development of coordination should be to manage the creation of adaptations in such a way that they are integrated and organized into a single functional system. The resulting functional system will allow the athlete to improve their sport-specific motor skills.

The **five principles** for selecting a training load for the development of coordination are based on adjusting the following:

- ***Complexity*** of movement:
    - Youth athletes – 40-75% level of complexity
    - Elite athletes – 75-100% level of complexity
- ***Intensity*** of loads:
    - Low (during the initial phase of learning)
    - Moderate (after the initial phase of learning)
    - Submaximal and Maximal (during the advanced phases of learning)
- ***Duration*** of exertion:
    - Dependent on the nature of the sport and its requirements (can be short or long)
- ***Number*** of repetitions:
    - 6-12 repetitions (depends on the intensity and complexity of the movement)
- ***Duration*** of rest between repetitions:
    - 1-3 minutes (depends on the intensity and complexity of the movement)

***Skill* – a complex, coordinated, *goal-oriented* motor act, which comprises a sequence of individual simple motor actions, developed during the training process until it can be realized with minimal conscious regulation (automatization) for the most effective achievement of a motor task while adjusting to external conditions.**

Successful sport performance can only be achieved if the athlete acquires the highest level of voluntary and non-voluntary **sport-specific techniques and motor functions,** which are necessary components of technical preparedness.



Any voluntary physical act consists of two inter-related structures – a **conscious** and a **motor** component. A *voluntary* motor act is achieved through intentional movement regulation and performed with a primary contribution from the higher levels of the CNS; i.e. with the help of human consciousness. In contrast, an *involuntary* motor act is characterized by habitual and unthinking behavior, or a lack of conscious regulation.

Rudimentary Ability

The goal of the training process is to create and develop skill until it can be realized with minimal conscious regulation. Before skill can be achieved, however, the following stages must be developed *sequentially*:

- Acquisition of specific *knowledge* about the techniques required to execute a motor act
- Development of rudimentary abilities to perform motor acts through the application of specific knowledge and repeated attempts to perform various motor actions and acts

Rudimentary Ability represents the elementary stage of performing sport-specific techniques and motor acts. The stage is characterized by the athlete's need to rely primarily upon voluntary regulation of a complete motor act and its individual motor actions. The athlete places more focus on executing the motor act and actions themselves, instead of the goal of the motor act.

During the process of developing Rudimentary Ability, the highest level of the CNS plays a leading role in finding an optimal way to execute a specific motor act. As a result, after consciously repeating a number of trials, the CNS establishes an ideal system and pattern of movements. The development of Rudimentary Ability is a prerequisite for the formation of skill.

Skill

Rudimentary Ability is perfected during the process of prolonged and consciously repeated motor acts in diverse conditions and environments, leading to a new stage in which the system and pattern of movements is *automatized*. Automatization is the process of transferring detailed regulation of movement from the *higher* (voluntary) level of the CNS to the *lower* (involuntary) levels. At this stage, the athlete's consciousness is no longer focused on performing the motor act and actions themselves, but has now shifted to achieving the *goal* of the motor act and adjusting to external conditions (i.e. game awareness).

The level of automatization differentiates Skill from Rudimentary Ability. The key distinguishing **features** are:

- ease of integration, execution, and correction of movement
- rhythm, smoothness, and efficiency of movement
- effective coordinated internal structure of movements
- consistency of movement repeatability
- high variability of movement selection/choice (situation dependent)
- stability of execution when exposed to adverse factors (fatigue, mental excitement, adverse climatic conditions, etc.)

Skill Formation

It is not enough to focus solely on performing multiple repetitions of a movement in the creation of a Skill – one must follow the *biological laws* of creating a Skill as well. During this process, the CNS performs a large number of modulations, trials, errors, and corrections; as a result, it finds the optimal way to execute a movement to achieve a motor task. In order for the CNS to find an optimal way, it must have at its disposal a large database of previously acquired techniques, motor acts, actions, and elements. In order to continuously develop, it is necessary to expand the database so that the CNS always has an opportunity to find ever better ways to achieve the motor task.

Skill is the result of new temporary connections being formed in the CNS, which are created in the following **phases**:

- *Irradiation* (distribution) of excitation in the nervous system characterized by generalized reactions involving unnecessary muscles while attempting to combine individual motor actions into a holistic act
- *Concentration* of excitation in the nervous system characterized by improved coordination, elimination of excessive muscular tension and high standardization of movements
- *Stabilization*, *coordination*, and *automatization* of movements

In addition, new skills are always created based on previously learned skills and abilities. The more complicated the skill, the more heavily the athlete relies upon previously learned skills and abilities.

When developing a Skill, it is vital to implement the correct means and methods from the very beginning. Correcting a Skill that was improperly developed requires significantly more time and effort than properly developing the Skill from the beginning.

Windows of Trainability for Coordination & Skill

As with power and strength, it is vital to determine whether prior adaptation processes in the nervous and muscular systems have been completed before applying a new training load. To this end, the Omegawave *Coach* product indicates whether the athlete has an open or closed window of trainability for the development of coordination & skill (fig. 10).

As discussed in the previous sections, when the window of trainability is *fully open* (fig. 10A), a variety of means and methods can be used to induce critical adaptations within the sport-specific functional system and achieve the maximal training effect.

When the window of trainability for coordination & skill is *partially open* for a limited training effect, the athlete's capability to develop this physical quality is reduced. Caution should be exercised in prescribing a training load.

When the window of trainability is *closed* (fig. 10B), no attempt should be made to develop coordination & skill at that time. This is because the sport-specific functional system is not ready to form ***new*** adaptations, as it is still in the process of adapting to previous loads. In this situation, the athlete can train to develop other physical qualities, if indicated by their measurements. In doing so, new adaptations will ensue in organs and systems in which recovery from previous loads has been completed (for example, the nervous system).

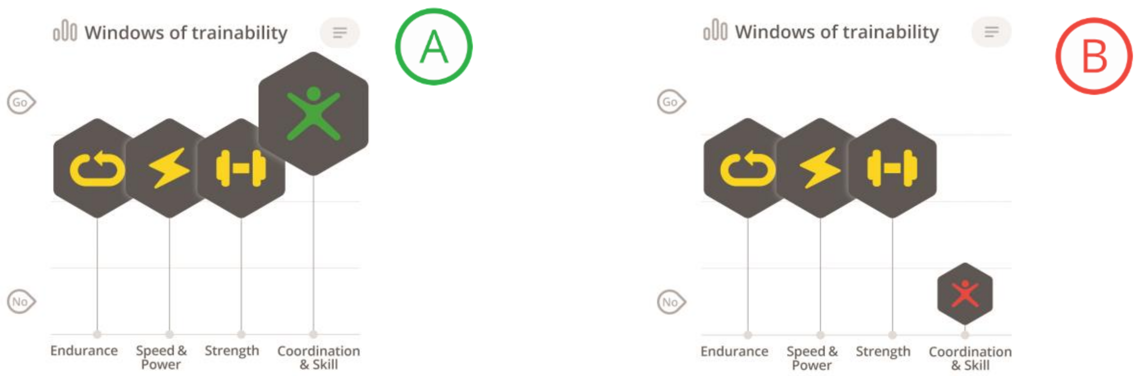


Figure 10. Open (A) and closed (B) windows of trainability for the development of coordination & skill.

WINDOWS OF TRAINABILITY™ FOR HEART RATE TRAINING ZONES

Heart Rate Zone **– a range determined by the frequency of cardiac contractions that indicates which energy system is primarily responsible for energy production at a specific moment in time.**

Energy is always required for the execution of muscle work. Energy for performing work comes from splitting ATP in the muscle. The initial amount of ATP in the muscle is relatively small – only enough to perform 1-2 seconds of work. In order to perform longer bouts of work, it is necessary to re-synthesize ATP constantly and to replenish its reserves. If the supply of ATP runs out, exhaustion sets in, and the athlete cannot continue to perform the task.

The three metabolic pathways that re-synthesize ATP in the muscle by means of chemical mechanisms are:

- ***Anaerobic Alactic*** – uses creatine phosphate as a source for re-synthesizing ATP, in the absence of oxygen.

  This system has *a very high capability* for energy production, but acts only for a short period of time. It is activated within 1 second of initiating work, but after 10 seconds it is exhausted due to limited supply.

- ***Anaerobic Lactic (glycolytic)*** – uses glycogen and glycolysis in order to re-synthesize ATP in the *absence* of oxygen. This results in a by-product of lactate and hydrogen ions.

  This system has a *high capability* for energy production. It is activated after 5 seconds of initiating work and reaches maximal output at approximately 20 seconds. It functions optimally between 30-90 seconds and becomes less effective after 5-6 minutes.

- ***Aerobic*** – uses carbohydrates and fats as the primary source for the re-synthesis of ATP in the *presence* of oxygen.

  The aerobic system assists the other two in the process of producing energy, but it greatly exceeds them in capacity and efficiency. Maximal output is reached after approximately 1.5-3 minutes and can last for hours.

Since both the aerobic and anaerobic lactic systems' capability for energy production is dependent on the presence or absence of oxygen in the muscle, measuring the level of activation of the cardiovascular system is an indicator of which metabolic pathway is involved.

Since the heart rate is a good indicator of the current activation level of the cardiovascular system, the *Coach* product is able to suggest individual and optimal ***heart rate zones*** for different types of activity (fig. 11).

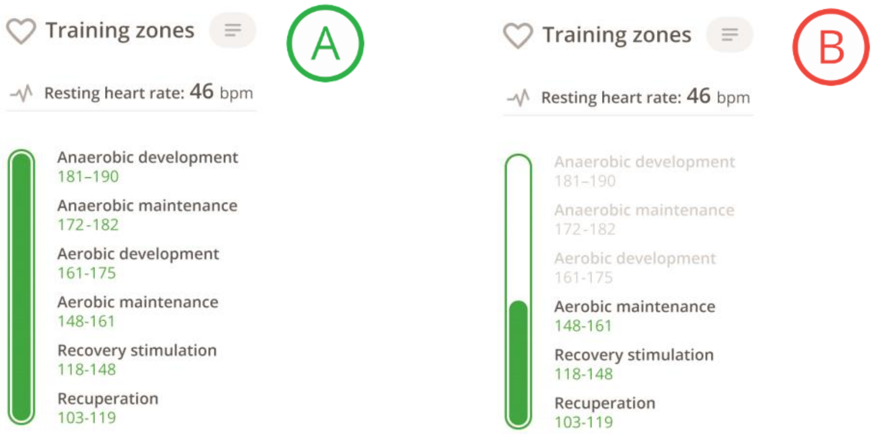


Figure 11. Open (A) and closed (B) heart rate zones for training.

If no other limiting factors are present, and the athlete has an open window for *all* heart rate zones (fig. 11A), a variety of means and methods can be employed in order to develop the energy systems. In this situation, the athlete will experience the maximal training effect.

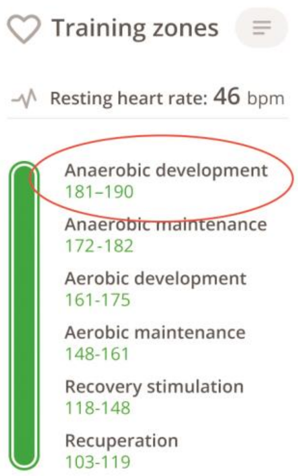
If there are only 3 heart rate zones open, and the other three are closed (fig. 11B), the cardio-respiratory system is limited in its ability to deliver oxygen to the muscle. Training at an intensity of 161 beats per minute or higher is not recommended. The best training effect can be realized at a lower intensity as indicated by the heart rate zones that are open.

Individual heart rate zones in the *Coach* product are calculated based on the identification of the athlete's ***heart rate at anaerobic threshold*** (HRAnT). The HRAnT is calculated with each assessment and can vary based on the athlete's changing metabolic processes. HRAnT is the key component that defines the *efficiency* of energy production during prolonged exercise, as well as being an indicator of the athlete's overall level of endurance. For example, in untrained individuals, the threshold could be 50% of maximal oxygen consumption (VO_2*max*), and in elite athlete athletes it can be 80%.

ANAEROBIC DEVELOPMENT

For this athlete, the anaerobic development heart rate zone is from ***181-190*** bpm and is above the individual's HRAnT. The dominant system of energy production in this heart rate zone is the **anaerobic glycolytic system.** A by-product of this type of metabolism is lactate, which considerably inhibits the ability of muscle function.

Training in these heart rate zones, provided that the window of trainability is *open*, allows the body to *develop* necessary adaptations for improved function of the anaerobic glycolytic energy system (e.g. increased power and capacity of lactic anaerobic processes).



Example for developing power:

- 30-90 second intervals (e.g. running)
- Maximal and/or submaximal intensity
- 4-6 exercises in a set
- 3-5 sets in a session
- 30-120 seconds of rest between exercises
- 5-6 minutes of rest between sets

Example for developing capacity:

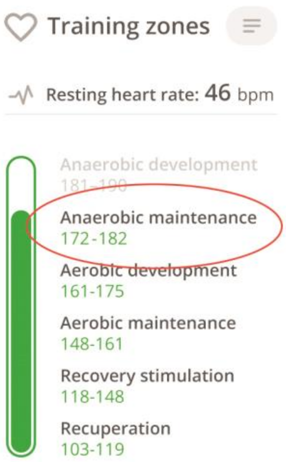
- 2-4 minute intervals (e.g. running)
- Sub-maximal intensity
- 4-6 exercises in a set
- 3-4 sets in a session
- 120+ second of rest between exercises
- 8-12 minutes of rest between sets

➔ Any sport specific activity that follows the guidelines of the examples can also be used.

(*Note: undertaking training in this heart rate zone is best done with caution, as doing so places intense stress on the cardiac system.*)

ANAEROBIC MAINTENANCE

For this athlete, the anaerobic maintenance heart rate zone is from ***172-182*** bpm. The lower end of the zone starts approximately at the HRAnT and the higher end of the zone is well above the HRAnT. The dominant system of energy production and the by-product of metabolism are the same as in the previous zone.



Training in this heart rate zone, provided that the window of trainability is *open*, allows the body to *maintain* pre-formed adaptations in the anaerobic glycolytic energy system (power and capacity of lactic anaerobic processes).

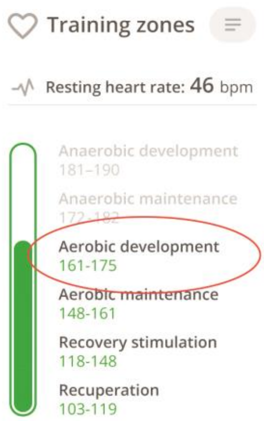
Exercises, combinations thereof, and methods of implementing this heart rate zone are similar to those described for the previous zone, but they must be carried out below 176 bpm.

(*Note: undertaking training in the anaerobic development zone – higher than 182 bpm – is not recommended as this raises the risk of undesired training effects.*)

AEROBIC DEVELOPMENT

For this athlete, the aerobic development heart rate zone is from ***161-175*** bpm. The higher end of the zone is approximately equal to the HRAnT while the lower end of the zone is well below the HRAnT. The dominant system of energy production is the **aerobic system**, resulting in no accumulation of undesirable by-products (i.e. lactate). However, when transitioning into higher heart rates inside this zone (i.e. 172-175 bpm) the anaerobic system can also take part in energy production.

Training in this heart rate zone, provided that the window of trainability is *open*, allows the body to *develop* critical adaptations in the aerobic system (i.e. significantly increase power and capacity of aerobic energy processes).



The power of aerobic processes can be defined as the level of VO_2max, and the capacity of aerobic processes can be defined by the duration of time the athlete can maintain their VO_2max.

(*Note: undertaking training in the anaerobic maintenance or anaerobic development zones – higher than 175 bpm – is not recommended as this raises the risk of undesired training effects.*)

Methods for developing aerobic qualities in this heart rate zone include:

Example for developing power:

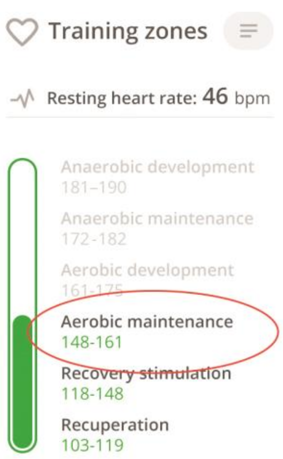
- 20-30 min. overall duration (running)
- 1-2 min. per interval
- 45-90 sec. rest between intervals
- Heart rate should not drop below 120 bpm during rest

Example for developing capacity and cardiac output:

- 30-120 min. overall duration (running)

AEROBIC MAINTENANCE

In this example, the aerobic maintenance heart rate zone is from ***148-161*** bpm**,** which is significantly lower than the HRAnT. The dominant system of energy production is the **aerobic system**.

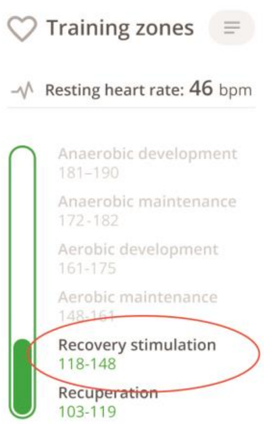


Training in this heart rate zone, provided that the window of trainability is *open*, allows the body to *maintain* previously formed adaptations in the aerobic system (e.g. power, capacity, and efficiency of the aerobic system).

Exercises, combinations thereof, and methods of implementing this heart rate zone are similar to those described for the previous zone, but they must be carried out below 161 bpm.

RECOVERY STIMULATION

In this example, the recovery stimulation heart rate zone ranges from ***118-148*** bpm. Performing work in this zone is designed to stimulate the processes of recovery in the body. The dominant system of energy production is the **aerobic system**.



Training in this heart rate zone, provided that the window of trainability is *open*, *stimulates* the process of recovery in the aerobic system – allowing the athlete to complete on-going adaptation processes.

Example for stimulating recovery:

- Sport related cyclical activities of an appropriate duration for recovery.

(*Note: undertaking training above 148 bpm is not recommended, as the cardiac system is not ready for greater loads.*)

RECUPERATION

In this example, the heart rate zone for recuperation is from ***103-119*** bpm. Performing work in this zone is designed to restore the body to a better condition. The dominant system of energy production is the **aerobic system**.

Provided that the window of trainability is *open*, this heart rate zone is intended for active rest and allows the athlete to complete adaptation processes within the aerobic system that were induced by previous loads of greater intensities.

(Note: undertaking work above 119 bpm is not recommended, as the cardiac system is not ready for greater loads.)

OVERALL READINESS – FOUNDATION FOR THE WINDOWS OF TRAINABILITY™

***Overall Readiness* – the current functional state of an athlete that determines the ability to effectively achieve their performance potential.**

The *Athlete Analysis* screen of the Omegawave *Coach* product displays the *Overall Readiness* of the athlete for training loads on a scale of 1 to 7; 1 being a state of very poor Readiness (fig. 12A) and 7 being a state of excellent Readiness (fig. 12B). Overall Readiness is the physiological *foundation* that defines Windows of Trainability™, and in turn Windows of Trainability™ is an indicator upon which correct training loads can be prescribed.

In order to identify the Overall Readiness of the athlete, the *Coach* product uses multiple scientific methods to accurately determine the current functional state of the three most important physiological systems of the body: Central Nervous System (CNS), cardiac and autonomic nervous system, and the metabolic system. (For more detail, refer to the section "Functional State of the Individual Systems" p. 48).

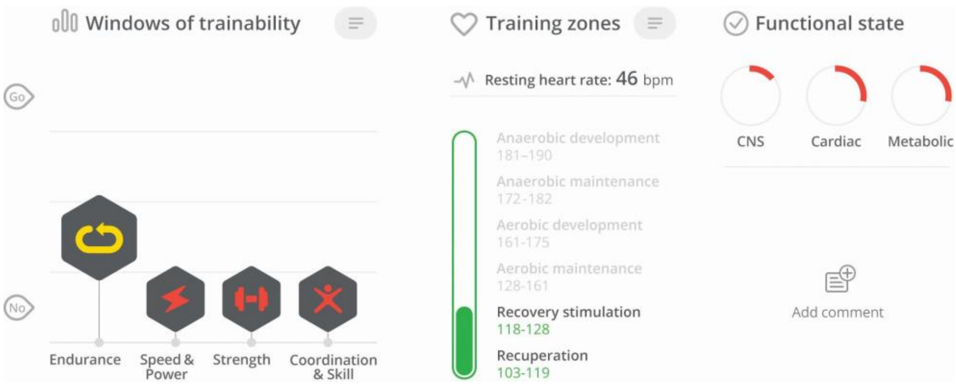


Figure 12A. A very poor Overall Readiness of the athlete.

The example above demonstrates a *very poor* Overall Readiness, all three systems – CNS, cardiac and metabolic – have factors severely limiting their function. The athlete is not ready for training loads of intensities higher than 128 bpm. The Windows of Trainability are closed for *speed & power*, *strength*, *and coordination & skill*. The athlete can develop *general endurance* by ensuring that the intensity does not exceed the recovery stimulation or recuperation heart rate zones.

As adaptation to previous training loads is not complete, applying new loads to these systems will require additional resources of the body that could lead to undesirable results – overreaching and a diminished training effect.

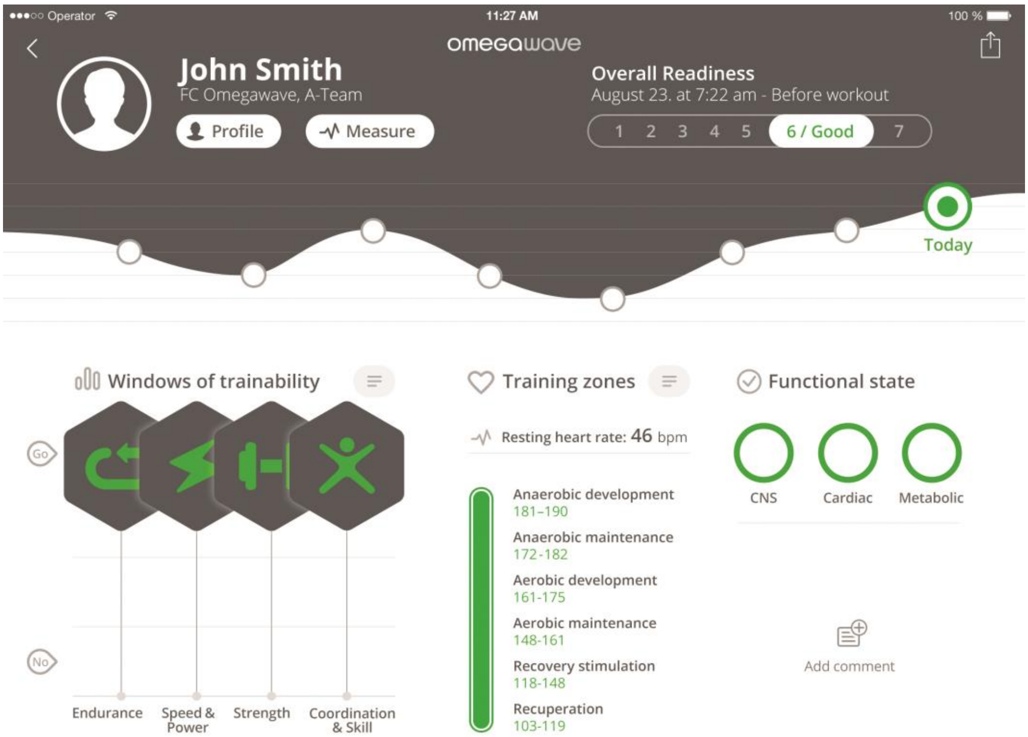


Figure 12B. An excellent Overall Readiness of the athlete.

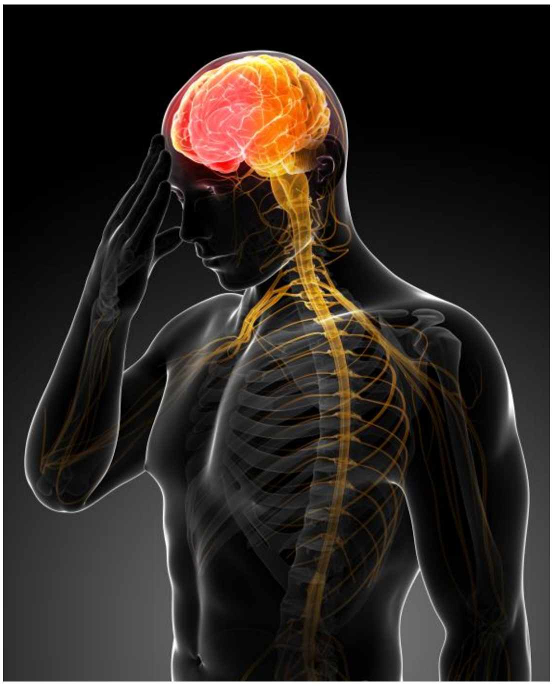
An *excellent* Overall Readiness (fig. 12B) demonstrates that all three physiological systems (CNS, cardiac, and metabolic) are functioning optimally, indicating a high Readiness to undertake any *volume* or *intensity* of training load. The window of trainability is *open* for the development of any physical quality – *endurance, speed & power, strength, and coordination & skill*. The athlete may train at any heart rate zone. It is an ideal time to form adaptations in the most important components of the sport-specific functional system, improve motor skills, and improve the overall sport mastery of the athlete.

To successfully manage the training process, it is important to track short and long-term adaptations to various forms of training loads. The Athlete Analysis page graphically displays the fluctuations over a period of time in the Overall Readiness, as well as the individual physiological systems and their constituent indices (fig. 12). This information can be used to evaluate the on-going process of adaptation and undertake measures to improve training.

FUNCTIONAL STATE OF THE INDIVIDUAL SYSTEMS

CENTRAL NERVOUS SYSTEM

***Functional state of the CNS* – level of activation and intensity of functioning at a specific moment in time.**



The functional state of the CNS reflects its capability to create an effective reaction to training and to form useful adaptions.

To assess the functional state of the CNS, the Omegawave *Coach* product utilizes the Direct Current Potential method to record and analyze the ***superslow bioelectric activity*** of the athlete's brain [1, 2]. The behavior of this activity over the course of a 3-minute assessment taken at rest indicates the Readiness of the CNS to regulate the body's functions.

More specifically, the assessment identifies the quality of adaptations, and the stability and Readiness of the CNS for upcoming training loads.

The following are examples of three different states of the CNS: excellent, moderate, and poor (fig. 13).

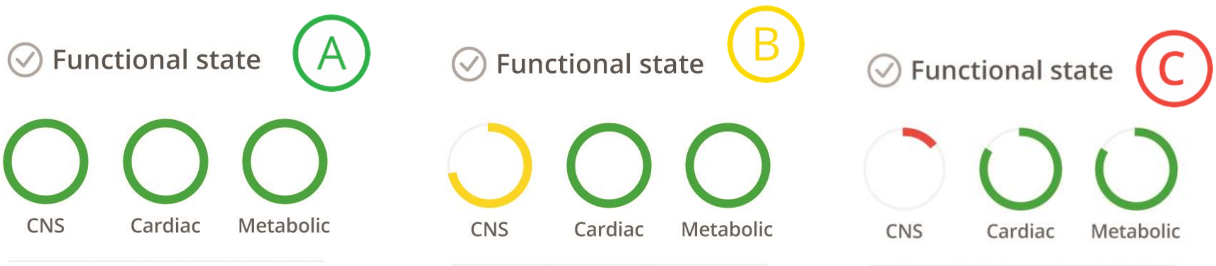


Figure 13. Functional state of the CNS: ideal (A), sufficient (B), insufficient (C).

IDEAL FUNCTIONAL STATE OF THE CNS

An *ideal* functional state of the CNS (fig. 13A) indicates that the CNS is not a limiting factor in selecting the type, volume and intensity of the training load. Provided that there are no limiting factors in the other systems (fig. 14), the athlete is able to train in any heart rate zone and develop any physical quality – *endurance*, *speed & power*, *strength*, and *coordination & skill*.

It is also an ideal time to form adaptations in the most important components of the sport-specific functional system, improve motor skills, and improve the overall sport mastery of the athlete.

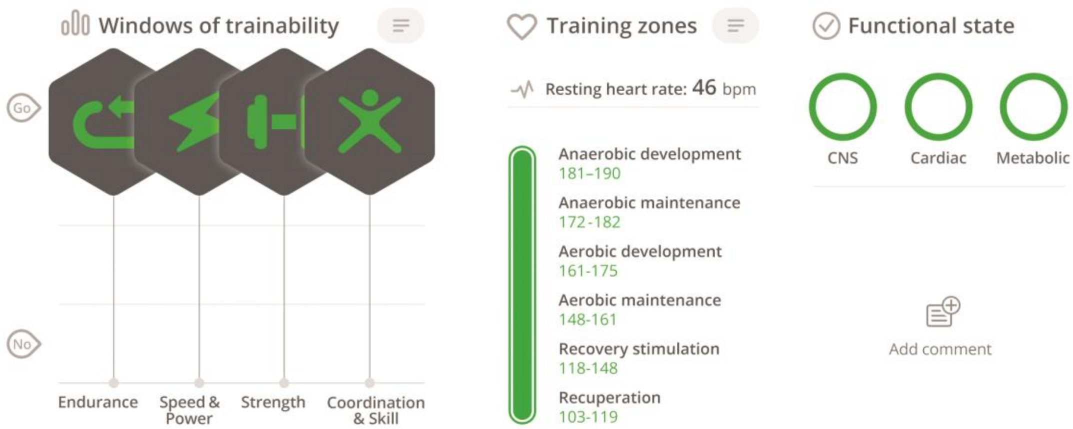


Figure 14. Ideal functional state of the CNS, cardiac, and metabolic system.

In the example below (fig. 15), the functional state of the CNS is ideal, yet there are limitations in the other systems – *cardiac* and *metabolic* – so the Overall Readiness is adversely affected. The window of trainability is open for *moderately* developing coordination & skill, while targeting endurance, speed & power, and strength would result in maintaining their level of development. In addition, it is advisable not to exceed 160 bpm in training.

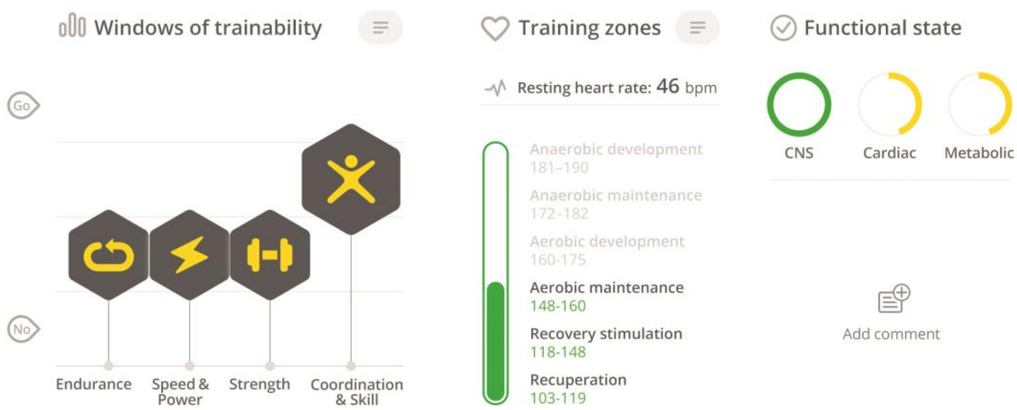


Figure 15. Ideal functional state of the CNS and limitations in the cardiac and metabolic systems.

SUFFICIENT FUNCTIONAL STATE OF THE CNS

A *sufficient* functional state of the CNS (fig. 13B) indicates that there are limitations resulting in a sub-par level of functioning. The level of activation of the CNS demonstrates either tension (hyperactivity), or fatigue (hypoactivation), meaning that the process of adapting to previous loads has not been completed. Once these adaptations have been completed, appropriate stimulation of the CNS via training loads can be resumed.

In the example below, the CNS is only *sufficiently* ready and there are no limitations in the other systems. The athlete can undertake training aimed at developing endurance. The other qualities may also be developed, however the training effect will not be as substantial.

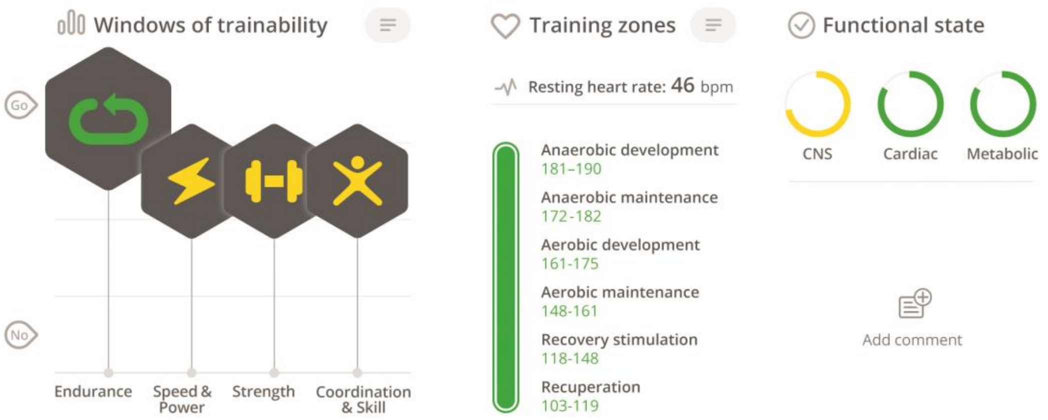


Figure 16. Sufficient functional state of the CNS and no limitations in the other systems.

When the CNS is in a *sufficient* functional state and there are significant limiting factors in the other systems (fig. 17), the training session should be constructed differently. The session can still aim to develop endurance, but only within heart rates below 169 bpm (the window of trainability is less open than in the example above). For strength, speed & power, and coordination & skill, exercises can only be employed to maintain the current level of development as the windows of trainability are almost closed.

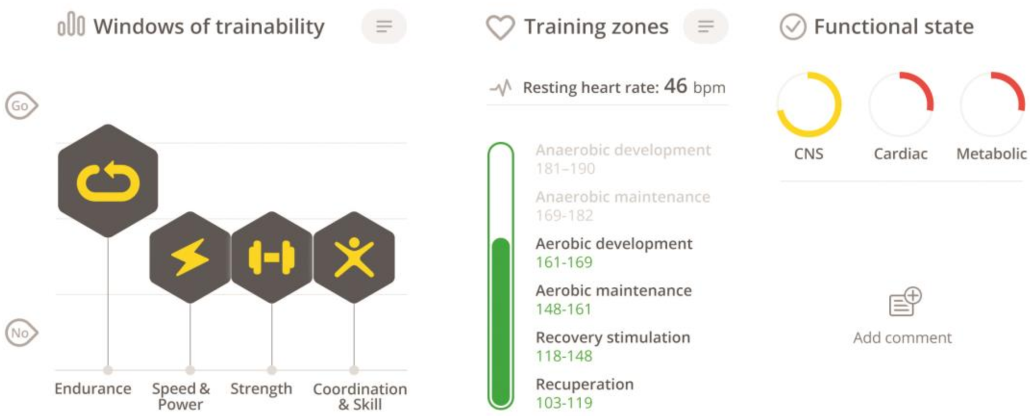


Figure 17. Sufficient functional state of the CNS and significant limitations in the other systems.

INSUFFICIENT FUNCTIONAL STATE OF THE CNS

An *insufficient* functional state of the CNS (fig. 13C) indicates that there are significant factors limiting its capability. The level of activation of the CNS demonstrates that it has been overloaded, resulting in significant fatigue or exhaustion. The CNS should be allowed to recover before applying training loads that overly stimulate it.

In the example below, the CNS is *not* ready, while there are *no* limitations in the other systems (fig. 18). Therefore, the athlete can undertake training aimed at moderately developing the qualities of endurance or strength, while the developmental level of speed & power and coordination & skill can be maintained.

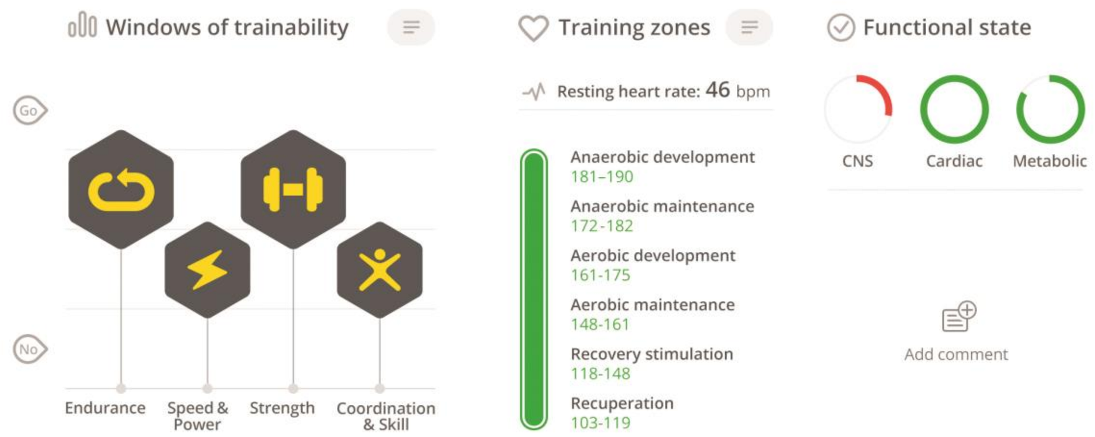


Figure 18. Insufficient functional state of the CNS and ideal functioning of the other systems.

In a situation when the CNS is in an *insufficient* functional state and there are significant limiting factors in the other systems (fig. 19), training prescription should be re-examined. The athlete can still carry out exercises aimed at retaining the current level of development for the qualities that display partially open windows of trainability, for example endurance and/or strength. Development of speed & power and coordination & skill are not recommended, as the window of trainability is closed completely.

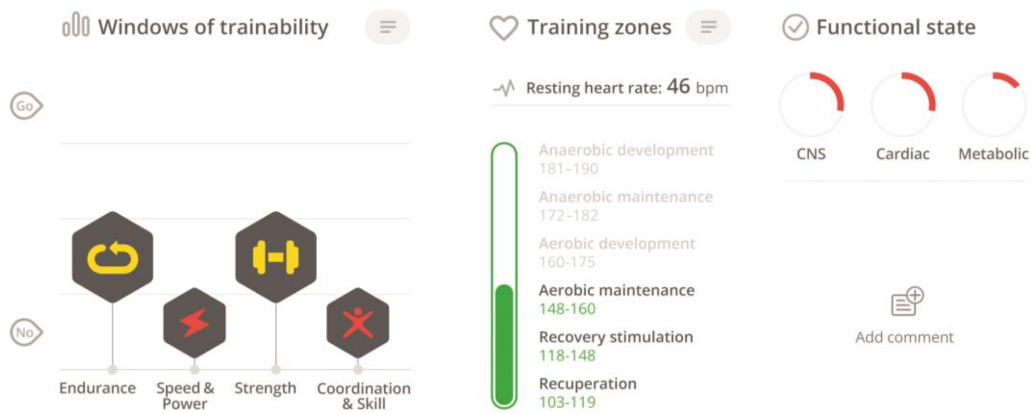


Figure 19. Insufficient functional state of the CNS and significant limitations in the other systems.

COMPONENTS OF CNS READINESS

CNS Readiness – a comprehensive indicator of the current state of the CNS presented on a scale of 1 to 7; 1 being a very poor state of Readiness and 7 being an excellent state of Readiness. The current state of the CNS determines its ability to effectively regulate the functions of the body in order to achieve useful adaptive results from training (fig. 20).

Figure 20. The Readiness of the CNS for training loads.

DC Potential – the present activation level of the frontal brain's systems that comprise the integrative center [1].

The DC Potential of the brain gauges the level of activity of the brain's superslow control system, responsible for managing the body's comprehensive and systemic adaptive response to training loads (fig. 21). In addition, DC Potential reflects the level of wakefulness and mental activation, resistance to stress, compensatory capacity and the cost of biological adaption during the preparation process. At a more complex level, DC Potential reflects the degree of coordination and inter-system neurohormonal relationships as primarily regulated by the CNS and the autonomic nervous system.

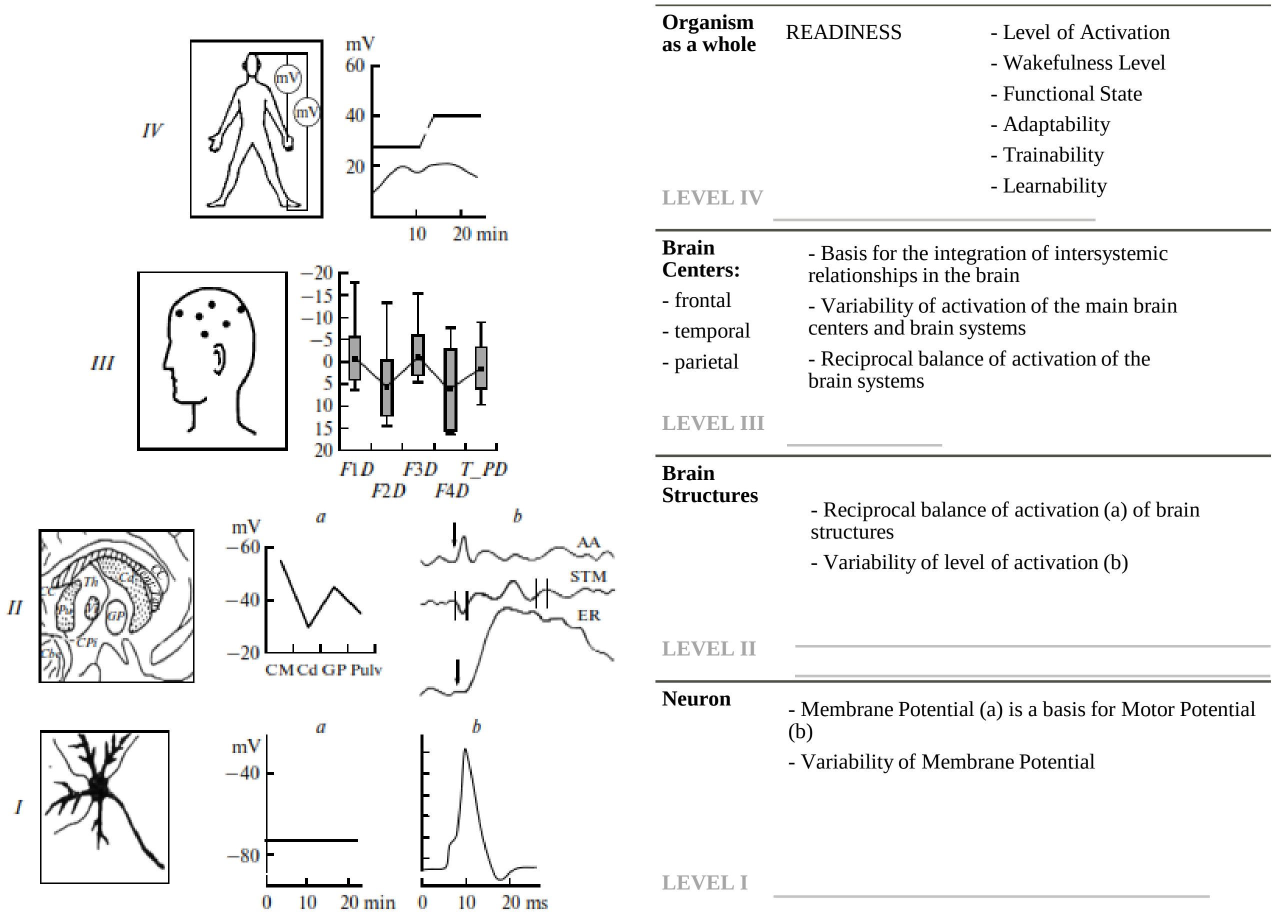


Figure 21. The Superslow Regulatory System of the Brain(adapted from Ilyukhina, 2011).

Taken at rest, Omegawave *Coach* measures superslow bioelectric signals of the brain (range between 0 to 0.5 Hz) using a vertex-thenar lead (forehead-palm). After analyzing these biological signals, the technology determines the amount of DC Potential in millivolts (mV), reflecting the operational state of rest and the Readiness to handle upcoming loads.

Based upon psychophysiological characteristics, DC Potential can be categorized into the following zones:

Optimal zone of DC at rest (25-45mV)

- Optimal level of wakefulness and mental activation
- Optimal, balanced, steady state of central brain mechanisms regulating the level of active wakefulness and operative rest
- Higher adaptive capacity of the body
- High productivity of cognitive activity and a high ability to learn
- Adequate response to any external influence: physical, mental, social and others
- High stress resistance
- The ability to spontaneously relax during the transition from a state of active wakefulness to a state of operational rest
- Psycho-emotional stability

Figure 22. Optimal zone of DC Potential at rest.

Increased zone of DC Potential at rest (more than 45mV)

- Increased alertness and mental activation
- Psycho-emotional tension and/or instability
- Suboptimal functioning of central brain mechanisms due to a high state of tension in the process of regulating the transition from active wakefulness to operational rest
- Low adaptive capacity of the body
- Limited cognitive activity and decreased learning ability
- Inappropriate reactions to certain physical, mental, social or other stimuli
- Low stress resistance

Figure 23. A higher zone of DC Potential at rest (a zone of high tension).

Reduced zone of DC Potential at rest (less than 0mV)

- Decreased alertness and mental activation
- Suboptimal functioning of central brain mechanisms due to a state of exhaustion (of varying intensities) in the process of regulating the transition from active wakefulness to operational rest
- Limited adaptive capacity of the body
- Reduced efficiency of cognitive activity and decreased learning ability
- Reduced adaptive reserves of the body
- Inappropriate reactions to certain physical, mental, social or other stimuli
- Reduced stress resistance
- Psycho-emotional instability

Figure 24. Reduced zone of DC Potential at rest (a zone of exhaustion).

To properly incorporate the use of DC Potential into a training plan, it is crucial to manage training loads in a way that allows the athlete to remain within the optimal zone. The athlete should not maintain measurements in a reduced or excited zone of DC Potential for extended periods of time. The optimal zone of DC Potential at rest reflects the most favorable time to apply training loads.

CHANGES IN THE FUNCTIONAL STATE OF THE CNS OVER TIME

As stated previously, it is important to track short- and long-term adaptations to various forms of loads in order to successfully manage each stage of the training process (i.e. single session, micro-, meso-, and macrocyle, training block, tapering/peaking). This information can be used to evaluate the ongoing process of adaptation and to undertake measures to adjust the training process accordingly [2]. To this end, the Omegawave *Coach* product graphically displays the fluctuations in the functional state of the CNS over a period of time (fig. 25).

The example below (fig. 25) graphs the successful preparation of a professional boxer to peak for a world title match. The fight took place on the 30th, marked with a star. A normal level of activation for the CNS is between 0-45 mV, with the optimal range being 25-40 mV. Values less than 0 mV indicate that the CNS is in a state of fatigue, and if the value drops below -20 mV the CNS enters a state of exhaustion. Values higher than 45 mV indicate that the CNS is in a state of heightened tension.

From the 5th to the 9th, the functional state of the CNS was in the lower end of the normal zone. The boxer's coach selected training loads that matched his athlete's requirements for successful adaptation, and in response the level of activation began to continually increase, reaching an optimal level of functioning on the 16th (fig. 25A). At this peak level, the athlete's stress resistance was at its highest and the CNS worked most effectively in the process of adaptating to stimuli.

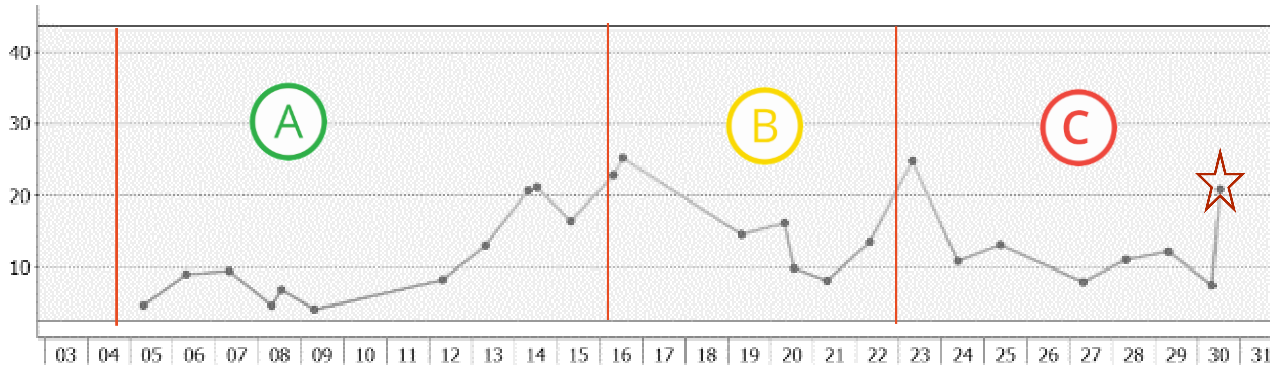


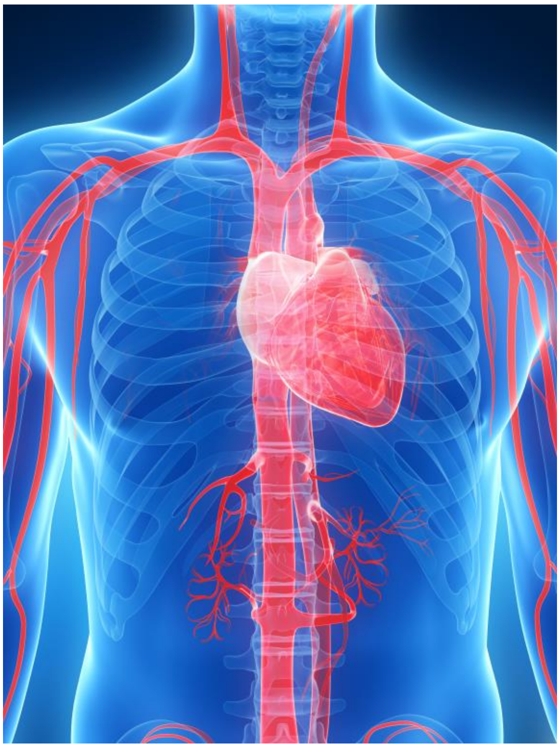
Figure 25. Fluctuations in the functional state of a boxer's CNS during preparation for a match.

Training loads over the following 5 days were selected to produce a slight drop in values (fig. 25, section B), with a return to the peak level on the 23rd. During the ensuing week, significant training loads were not applied and the athlete's CNS maintained a normal level of functioning. As anticipated, values rose again on the day of the fight to the peak level indicating a high level of wakefulness and the capability to realize the highest level of preparedness (fig. 25, section C).

As shown, frequent monitoring of the functional state of the CNS is an important factor in defining the overall Readiness of the body, which in turn allows the coach to successfully manage the training process based on individual physiological feedback from the athlete [3, 4].

CARDIAC SYSTEM

Functional State of the Cardiac System – level of functioning and tension of the cardiac system at a specific moment in time.



The functional state of the cardiac system reflects the current integrated response of the multi-level system that regulates cardiac function in the process of adapting to training loads.

The role of the cardiac system is to form critical and useful adaptations that lead to an improved trained-state of the athlete. The level of the functional state is an indicator of the cardiac system's capability to perform this role.

To assess the functional state of the cardiac system, the Omegawave *Coach* product uses a comprehensive and integrated analysis of ***Heart Rate Variability*** (HRV). This method has proven its reliability and usefulness in assessing the cardiac system's adaptations to training load, and is actively used in our technology [5-17] .

The *Coach* product's analysis of HRV complies with the Standard of Registration and Physiological Interpretation for Clinical Use, as defined by the European Society of Cardiology and the North American Society of Pacing and Electrophysiology [18]. In addition, the product draws on international research to utilize additional analysis methods, such as: statistical and spectral analysis, geometrical analysis (variation pulsometry), and non-linear and integral analysis methods.

Based on fifteen years of experience in applying the HRV method among thousands of elite athletes, the Omegawave *Coach* product incorporates the use of proprietary models, algorithms and a unique Expert System (see. appendix) to comprehensively analyze the bioelectrical activity of the heart.

From a 3-minute assessment, the *Coach* product identifies the levels of **Stress**, **Adaptation Reserves**, and the **Recovery Pattern** of the cardiac system – reflecting an accurate picture of its Readiness for training loads (fig. 26).

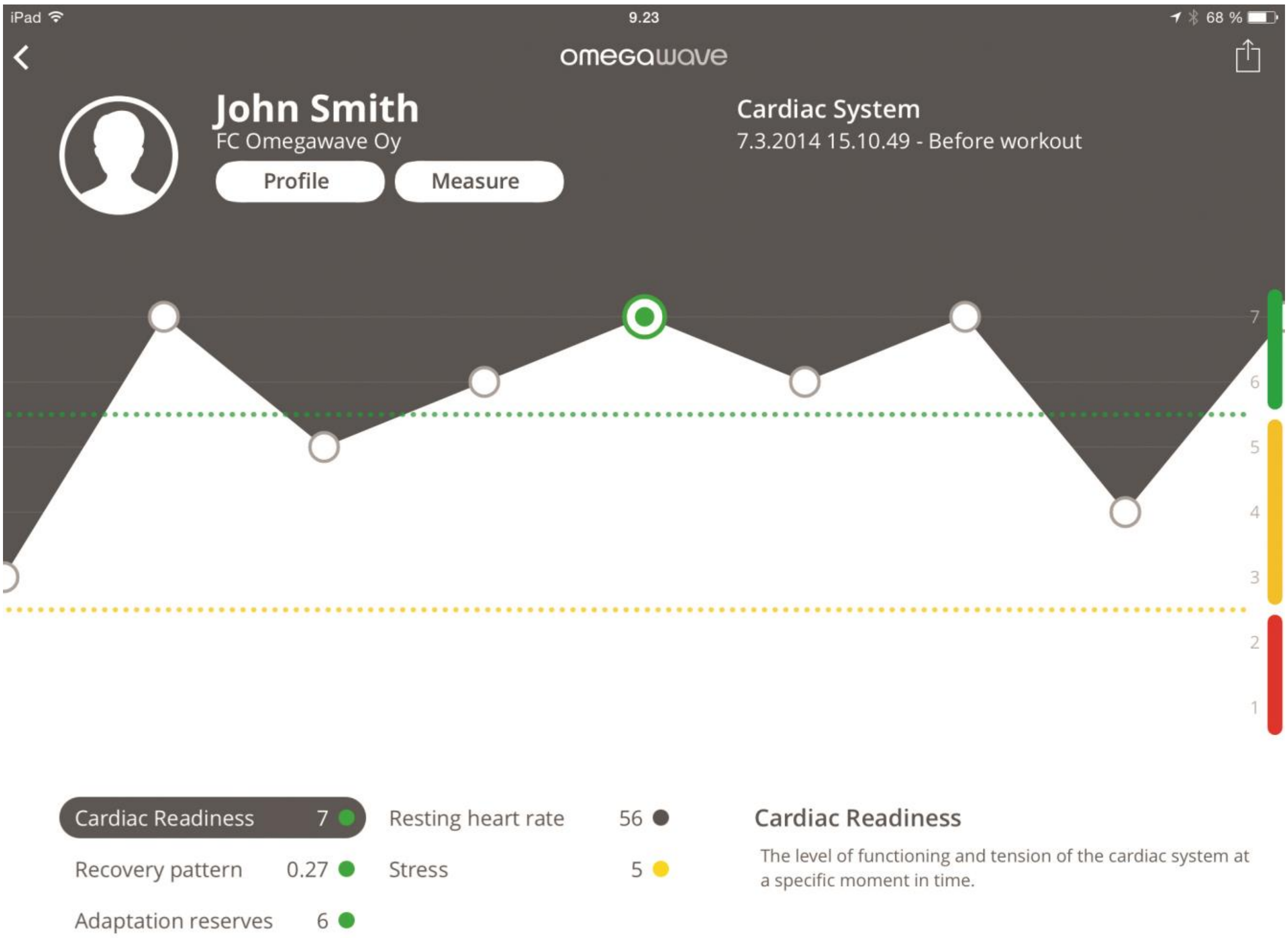


Figure 26. Various levels of Cardiac Readiness.

The following examples represent three different states of the cardiac system: ideal, sufficient, and insufficient (fig. 27).

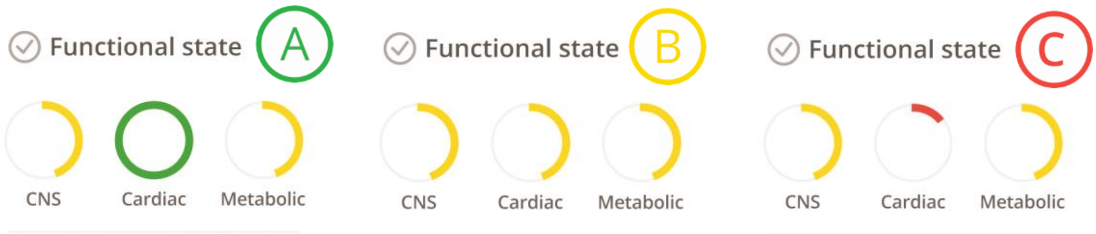


Figure 27. Three functional states of the cardiac system.

IDEAL FUNCTIONAL STATE OF THE CARDIAC SYSTEM

An *ideal* functional state of the cardiac system (fig. 27A) reflects that it is not a limiting factor in selecting the type, volume and intensity of the training load. Provided that there are no limiting factors in the other systems (fig. 28), the athlete is able to train in any heart rate zone and develop any physical quality – endurance, speed & power, strength, and coordination & skill.

It is the *best* time to form and maintain critical adaptations in the sport-specific functional system. Appropriate training loads will produce a positive training effect and improve the trained-state of the athlete.

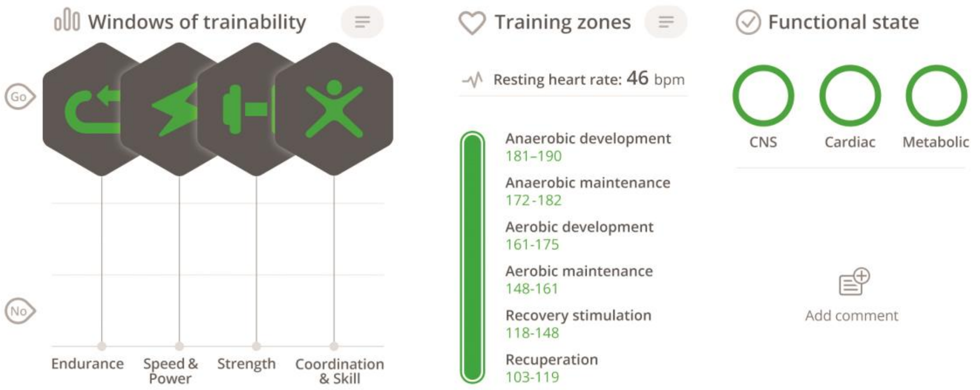


Figure 28. Ideal functional state of the cardiac system with no limitations in the other systems.

In figure 29, the functional state of the cardiac system is ideal, yet there are limitations in a different system – *CNS* – so the athlete's overall Readiness is adversely affected. Developing endurance and/or coordination & skill will result in the highest training effect, while targeting speed & power or strength would result in only a moderate training effect.

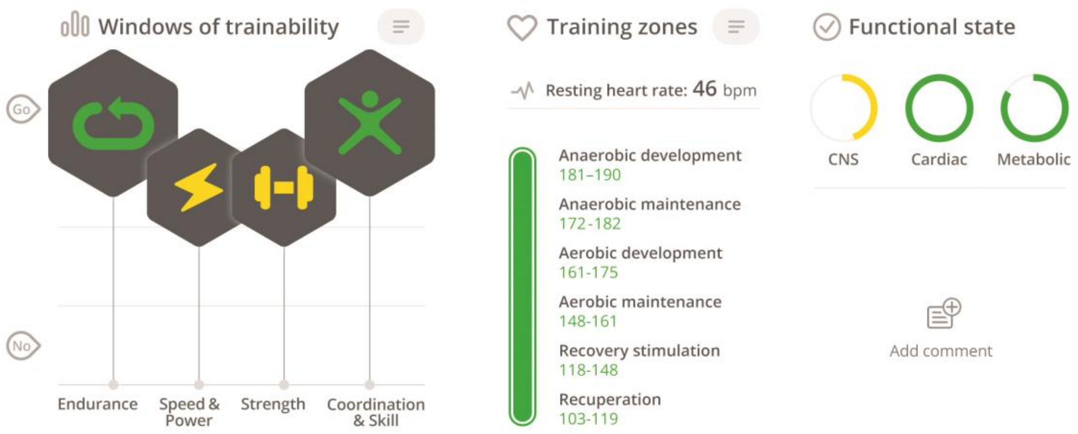


Figure 29. Ideal functional state of the cardiac system with limitations from the CNS.

SUFFICIENT FUNCTIONAL STATE OF THE CARDIAC SYSTEM

A *sufficient* functional state of the cardiac system (fig. 27B) indicates that the system is functioning at a sub-par level, showing signs of tension and possibly fatigue. The process of creating useful adaptations to previous loads is still ongoing. Once these adaptations have been completed, appropriate stimulation of the cardiac system via training loads can be resumed.

In the example below, the cardiac system is only *sufficiently* ready and there are no limitations in the other systems (fig. 30). The athlete can undertake training aimed at developing endurance. The other qualities may be moderately developed, though the training effect will not be as substantial.

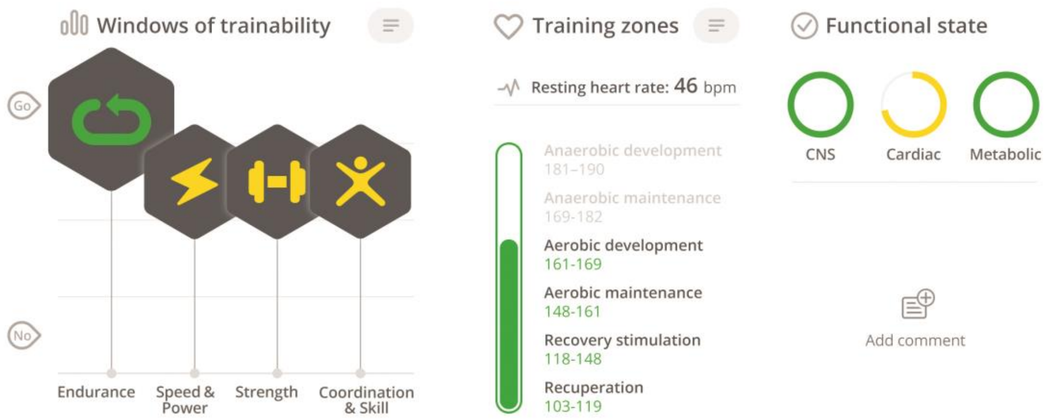


Figure 30. A sufficient functional state of the cardiac system and no limitations in the other systems.

In the example below, the cardiac system is in a sufficient functional state and there are limiting factors in the other systems (fig. 31); the training session should be constructed differently. The session can still aim to moderately develop endurance, but only within heart rates below 169 bpm. For speed & power, strength, and coordination & skill, the level of development can still be retained through training, as the window of trainability is partially open.

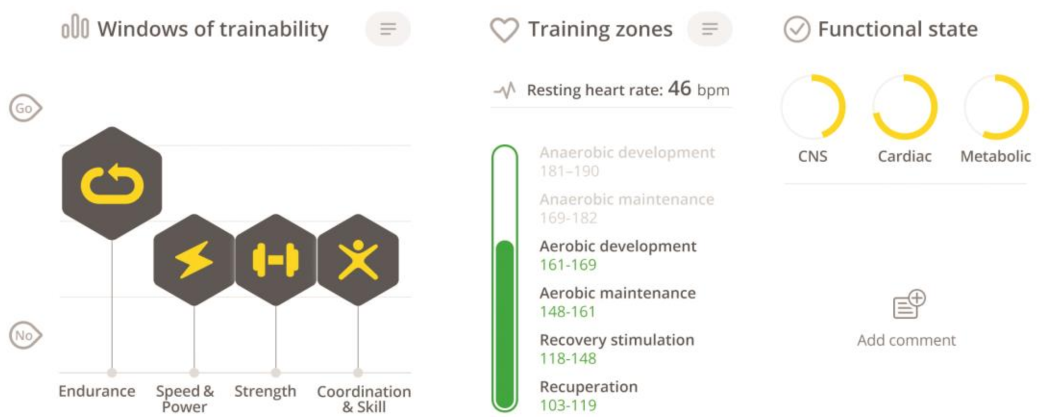


Figure 31. Sufficient functional state of the cardiac system with limitations from the CNS and metabolic system.

INSUFFICIENT FUNCTIONAL STATE OF THE CARDIAC SYSTEM

An *insufficient* functional state of the cardiac system (fig. 32) indicates that there are *significant* factors limiting its capability, showing signs of tension and possibly exhaustion. The cardiac system is occupied by the process of adapting to previous loads, therefore it should be allowed to recover before applying new loads that overly stimulate it.

In the example below, the cardiac system is *not* ready, but there are no limitations in the other systems (fig. 32). Therefore, the athlete can undertake training at an intensity of 128 bpm or below to maintain the developmental level of endurance. Developing the other qualities is not recommended, as the windows of trainability are closed.

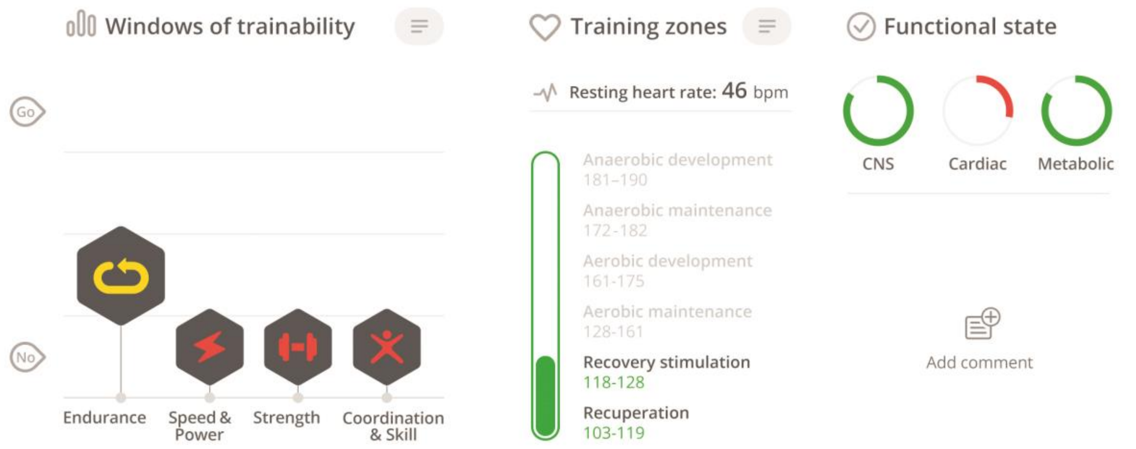


Figure 32. Insufficient functional state of the cardiac system with no limitations in the other systems.

When the cardiac system is in an insufficient functional state and there are *significant* limiting factors in the other systems (fig. 33), training prescription should be fully reviewed. The athlete is not advised to attempt to develop any physical qualities as the windows of trainability are fully closed.

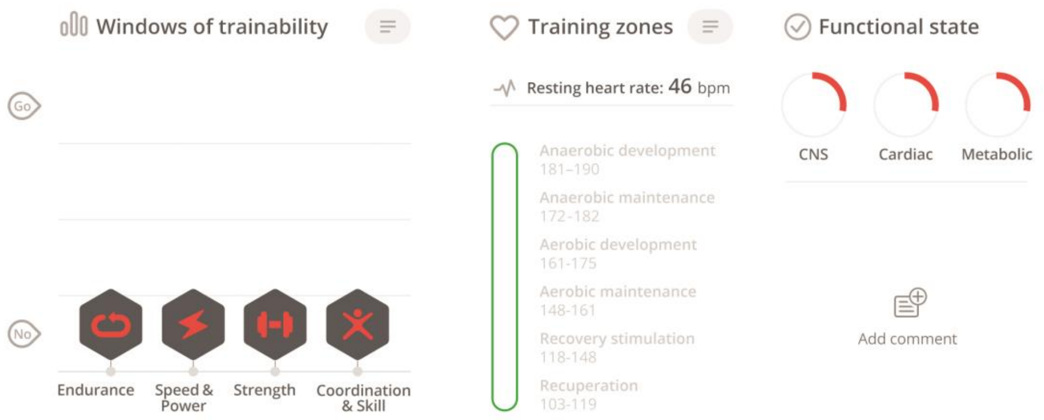


Figure 33. Insufficient functional state of the cardiac system and significant limitations in the other systems.

RESTING HEART RATE

By measuring the function of the cardiac system at rest, Omegawave *Coach* allows for the athlete's resting heart rate to be tracked over time (fig. 34).

Resting Heart Rate (RHR) – an integrative physiological indicator of the functional state of the cardiac system. The norm for untrained individuals is between 60-90 bpm; known as *normocardia*. Under adverse conditions (i.e. illness, chronic excessive exercise, etc.) the RHR may rise significantly, up to 100 bpm or more; known as *tachycardia*. Trained individuals, particularly those involved in cyclical sports, can experience a RHR of below 60 bpm; known as *bradycardia*. This is a normal result and is brought on by adaptive responses resulting in a high vagal tone.

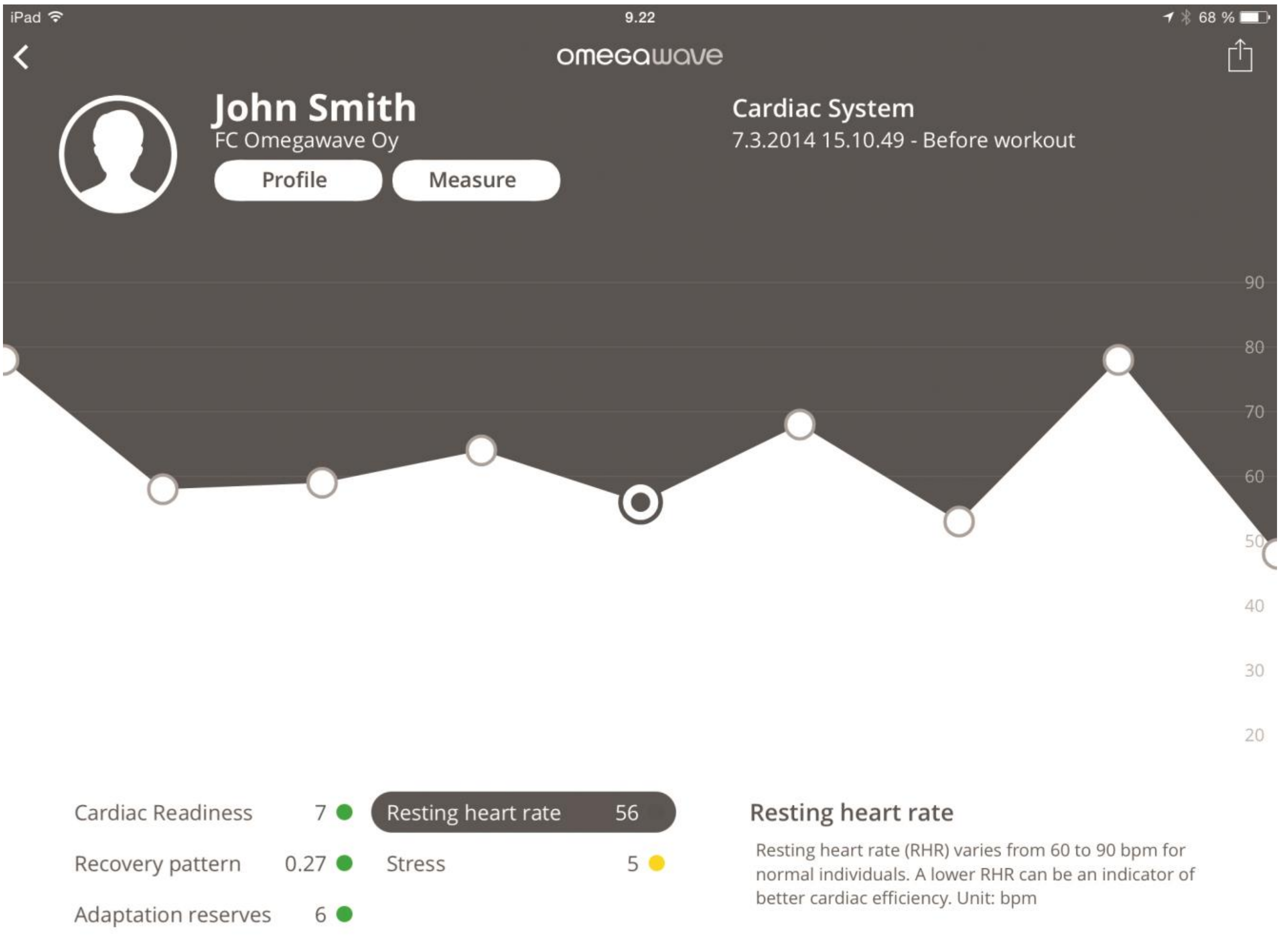


Figure 34. An individual's resting heart rate over time.

STRESS

Stress – the level of tension in the cardiac system in response to physical and mental loads.

A key component in managing the training process is to monitor the effect of prescribed doses of stress in the cardiac system over time. The level of stress in the cardiac system determines its Readiness for upcoming training loads. A state of excessive stress (fatigue) can be caused by prolonged and improper management of training loads.

In order to identify a state of fatigue, the Omegawave *Coach* product quantifies the ***level of stress*** in the cardiac system on a scale of 1 to 7; 1 being a very high level of tension and 7 being very low level of tension (fig. 35). With this information, training and recovery activities can be customized to the needs of the athlete.

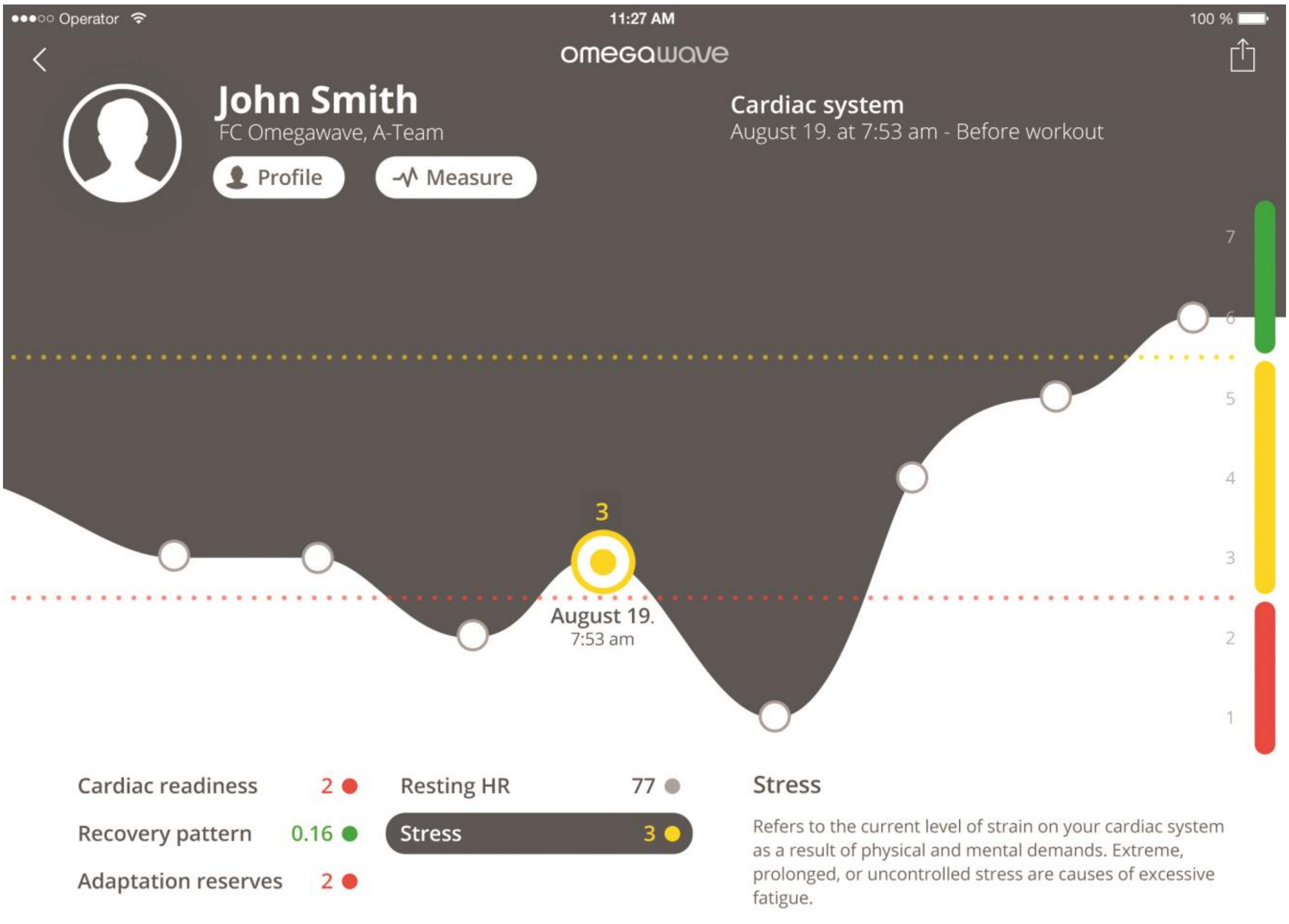


Figure 35. Various levels of stress in the cardiac system.

The level of stress indicates the state of the central circuit’s regulation of heart rate and reflects the influence of central mechanisms (higher level) of regulation on the function of autonomic mechanisms (lower level). The level of stress is significantly determined by the level of sympathetic tone. Under adverse conditions (e.g. high physical or mental stress, illness, etc.) stress can increase substantially. In this case, autonomic regulation of the heart is no longer sufficient, and the highest levels of the CNS become involved. However, as those levels of the CNS become more involved, centralization of regulation also increases, resulting in higher levels of stress in the cardiac system. The opposite is also true: stress is reduced when the cardiac system is regulated by autonomic mechanisms. When based on mechanisms of self-regulation, adaptive reactions in the body will have their optimal effect.

Causes of excessive stress include:

- Prolonged physical and mental loads
- Inadequate recovery
- Unbalanced and irregular meals
- Unbalanced ratio between work and rest
- Poor environmental conditions

Consequences of unmanaged stress include:

- Decreased adaptation reserves of the cardiac system
- Unpredictable training effect
- Onset of chronic stress
- Onset of overtraining
- Onset of illness and injury
- Decreased work capacity and performance results

Excessive stress can be avoided by:

- Proper selection and application of physical and mental loads with sufficient recovery
- Balanced and regular meals
- Balanced ratio between work and rest
- Improved environmental conditions

Positive results of proper stress management:

- Control of the training process
- Reduced likelihood of excessive stress
- Increased work capacity and performance results
- Reduced likelihood of overtraining
- Reduced risk of illness and injury

ADAPTATION RESERVES

Adaptation Reserves – a measure of how long and effectively the cardiac system can express the ability to adapt to external stimuli.

Adaptation reserves reflect the capacity of the cardiac system to form a positive, useful adaptive response to training. The athlete's cardiac system is able to effectively adapt to the effects of training and withstand stress when the reserves are between 3 and 7. If the reserves are exhausted (a value of 1 or 2), the cardiac system will not be able to adequately compensate for the physiological changes caused by stress; therefore, the athlete will be unable to form a useful adaptive result (fig. 36). Trained individuals often exhibit higher adaptation reserves than untrained individuals.

Figure 36. Various levels of Adaptation Reserves in the cardiac system.

Causes of low adaptation reserves include:

- Chronic physical, psychological, and emotional stress
- Chronic training strain, overreaching, and overtraining
- Inadequate recovery
- Chronic illness
- Unbalanced or irregular meals

Prolonged low adaptation reserve values are indicative of a state of chronic stress and overtraining. Associated risks of this condition include:

- Increased likelihood of sub-par performance results
- Increased likelihood of injury and illness

Low adaptation reserves can be avoided by:

- Proper management of physical, psychological, and emotional stress.
- Individualization of training loads
- Sufficient recovery activities
- Reducing the risk of injury or illness
- Proper diet management

Positive effects of maintaining high adaptation reserves:

- Increased capacity to handle physical, psychological, and emotional loads
- Increased capability of handling greater training loads
- Decreased risk of overreaching and overtraining
- Increased likelihood of successful performance results
- Decreased risk of injury or illness

Increasing the athlete's adaptation reserves allows the volume of resources in the cardiac system to be developed, providing the body with an additional opportunity to effectively manage useful adaptations in the development of a sport-specific functional system. This effect benefits training by allowing the athlete to significantly diversify the means and methods of preparation.

***Recovery Pattern* – indicates the current activation level of the parasympathetic nervous system's regulation of the cardiac system, which serves to maintain homeostasis and restore the functionality of the body after load.**

Reflects the quality of the recuperative processes in the cardiac system in response to training loads. In order to identify the quality of recuperative processes in the cardiac system in response to training loads, Omegawave *Coach* evaluates the contribution of vagus regulation to cardiac function. Optimal values for this index range from 0.16 to 0.41 sec (fig. 37). Optimal values range from 0.16 to 0.41 sec (fig. 37). High or low values indicate that the cardiac system is functioning outside established norms, reflecting a state of high tension during adaptation to training loads and an incomplete recovery process. Fluctuations within the optimal zone are acceptable. However, a higher value within the optimal zone is indicative of a more efficient recovery process.

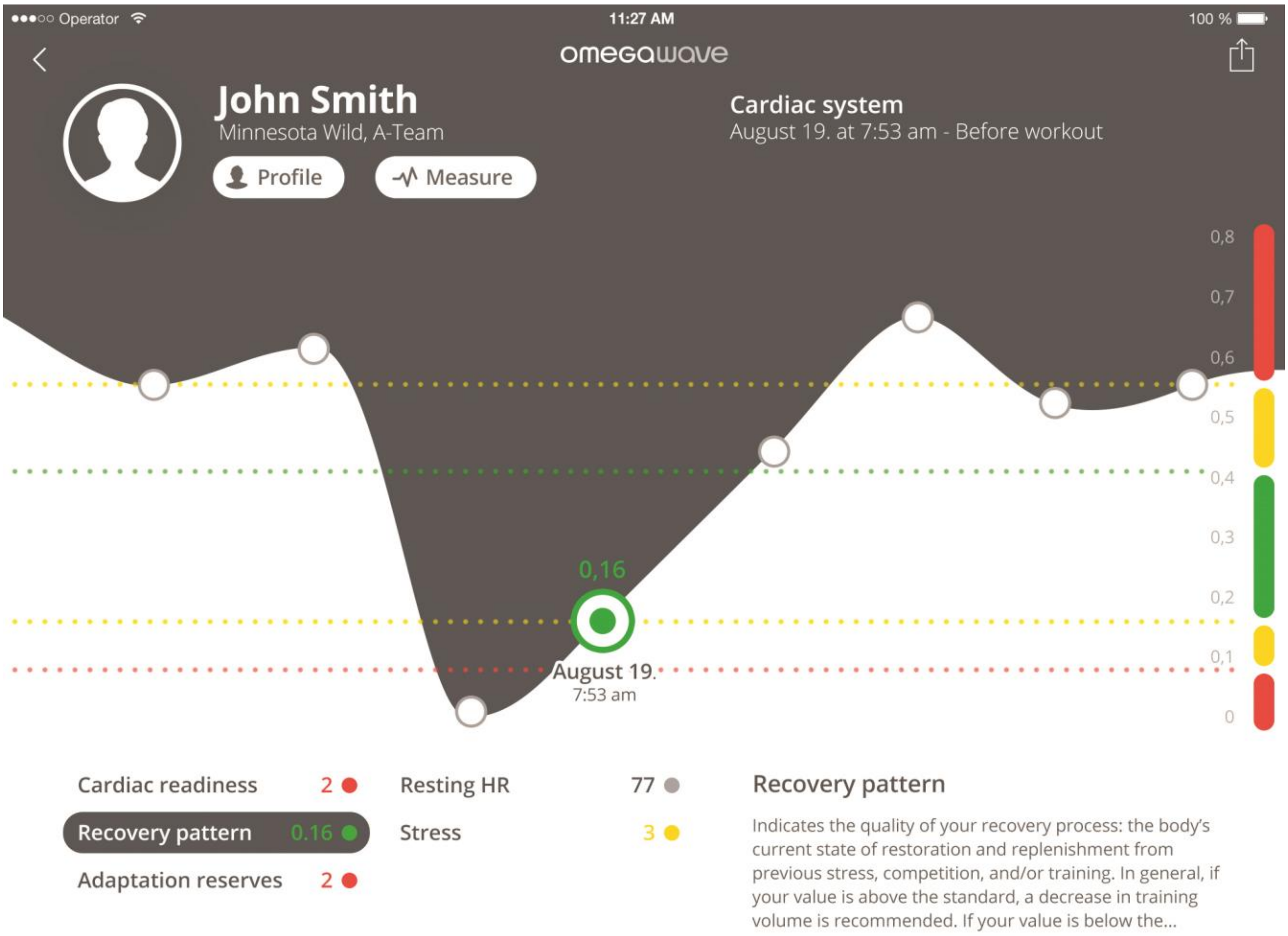


Figure 37. Various activity levels of the Recovery Pattern.

Trained individuals often exhibit higher values compared to untrained individuals (within the optimal zone). Also, endurance athletes exhibit higher values than sprinters. Regardless of the sport, most athletes exhibit a high activity of the parasympathetic branch of the autonomic nervous system – as indicated by high values of the recovery pattern – and a low activity of the sympathetic branch.

Causes of a low recovery pattern:

- Overload of physical and/or mental stimuli
- Unbalanced ratio between work and rest
- Illness and/or intoxication
- Unbalanced or irregular meals
- Lack of (or inadequate) recovery

Risks associated with a prolonged period of excessively low values:

- Increased risk of illness
- Increased probability of overtraining
- Increased probability of injury
- Increased probability of poor performance
- Reduced likelihood of effective recovery

Risks associated with a prolonged period of excessively high values:

- Increased probability of injury
- Increased probability of poor performance
- Increased probability of the onset of arrhythmia

Undesired recovery pattern can be avoided by:

- Selection of appropriate aerobic training loads
- Customization of recovery activities
- Balanced and regular meals
- Balanced ratio between work and rest

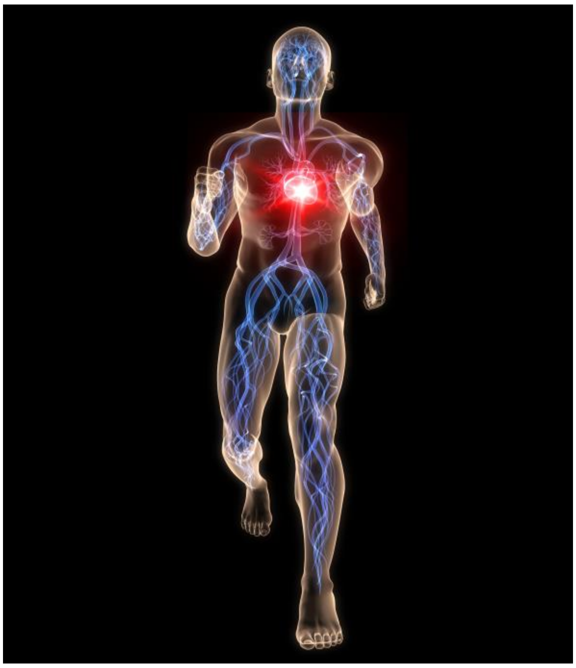
Positive effects of maintaining an ideal recovery pattern:

- Increased rate of recovery
- Increased work capacity
- Normalization of excitation and inhibition in the nervous system
- Decreased likelihood of prolonged stress
- Decreased risk of injury and illness

METABOLIC SYSTEM

***Functional State of the Metabolic System* – the level of efficiency of the energy supply system at a particular time in response to training loads.**

In order to evaluate the metabolic system's Readiness for upcoming loads, the Omegawave *Coach* product uses a complex amplitude-frequency analysis of the ECG. This proven and reliable method allows for accurate measurements of adaptations in the metabolic system.



The functional state of the metabolic system is evaluated according to the following indicators:

- ***Aerobic Readiness*** – reflects the current state of the aerobic metabolic pathway and the ability to perform aerobic work in training
- ***Anaerobic Readiness*** – reflects the current state of the anaerobic metabolic pathway and the ability to perform anaerobic work in training
- ***Metabolic Reaction Index*** – reflects the overall effectiveness and coordination of the metabolic system to support planned training loads, measured over longer periods of time

The following examples represent two different states of the metabolic system (fig. 38).

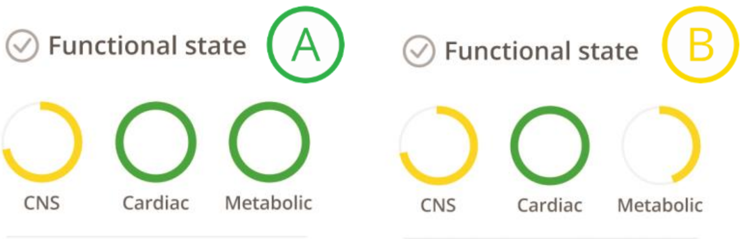


Figure 38. The functional state of the metabolic system: ideal (A) and sufficient (B).

IDEAL FUNCTIONAL STATE OF THE METABOLIC SYSTEM

An *ideal* functional state of the metabolic system (fig. 38A) indicates that it is not a limiting factor in selecting the type, volume and intensity of the training load. Provided that there are no limiting factors in the other systems (fig. 39), the athlete is able to train in any heart rate zone and develop any physical quality – endurance, speed & power, strength, and coordination & skill. This represents the best time to form and maintain critical adaptations in the sport-specific functional system. Appropriate training loads will produce a positive training effect and improve the trained-state of the athlete.

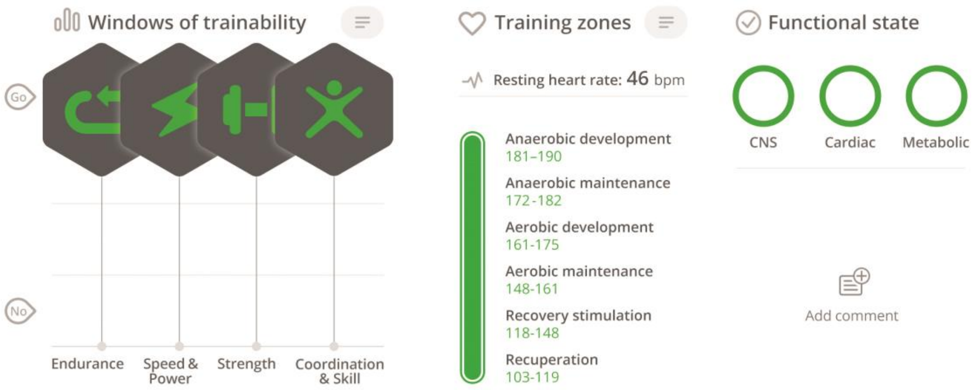


Figure 39. Ideal functional state of the metabolic system with no limitations in the other systems.

In the situation below (fig. 40), the functional state of the metabolic system is ideal, yet there are limitations in a different system – *CNS* – so the overall Readiness is adversely affected. Developing endurance and/or coordination & skill will result in the highest training effect, while targeting speed & power and strength would result in a lesser training effect.

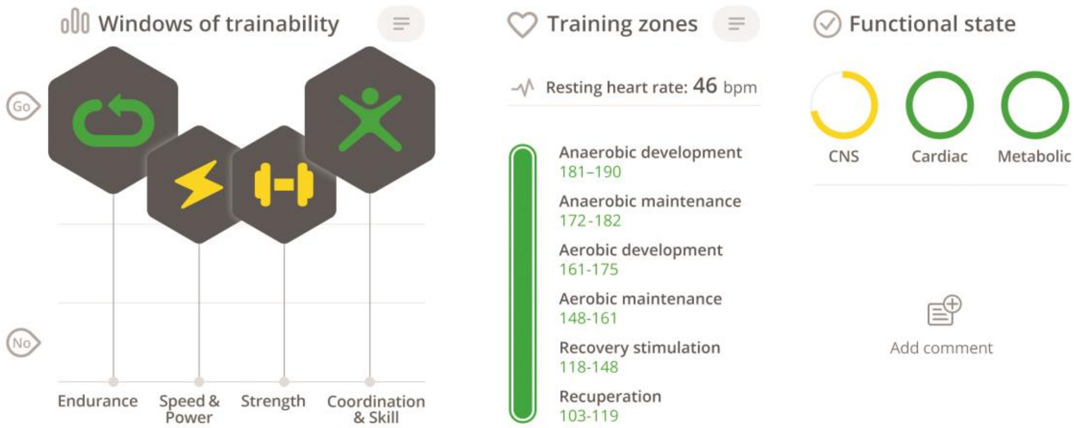


Figure 40. Ideal functional state of the metabolic system with limitations in the CNS.

SUFFICIENT FUNCTIONAL STATE OF THE METABOLIC SYSTEM

In the example below (fig. 41), the metabolic system is in a *sufficient* functional state and there are limitations in the other systems. Therefore, the training session should be constructed differently from above. For speed & power, strength, and coordination & skill, training can aim to maintain the level of development, but only within heart rates below 169 bpm; endurance can be moderately developed within the same zone.

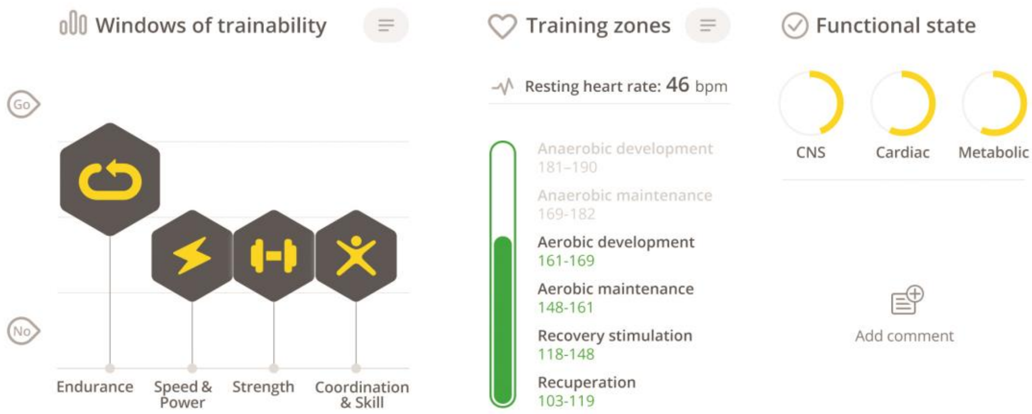


Figure 41. Sufficient functional state of the metabolic system with limitations in the other systems.

AEROBIC READINESS

Aerobic Readiness – reflects the current state of the aerobic metabolic pathway and the ability to perform aerobic work in training.

Training loads of an aerobic nature are characterized by a long duration of exertion at a high or moderate power output, during which the body is mainly fueled by aerobic sources of energy supply. For endurance activities (such as running 5km or swimming 1.5km), the aerobic system produces at least 70% of the required energy. Aerobic sources of energy supply are the basis for the development of endurance and reflect the ability to resist stress and fatigue while allowing for an increase in adaptation reserves.

Figure 42. Various levels of Aerobic Readiness.

Factors which may significantly lower Aerobic Readiness:

- Aerobic loads of large volume or intensity
- Lack of (or insufficient) recovery
- Unbalanced or irregular meals, especially a lack of carbohydrates
- Illness and intoxication

Risks associated with low Aerobic Readiness:

- Reduced level of trainability
- Reduced resistance to stress
- Accumulation of fatigue
- Reduced adaptation reserves
- Onset of illness and/or injury
- Decreased work capacity and performance

Factors that may increase Aerobic Readiness:

- Selection of appropriate aerobic training loads
- Adequate and complete recovery
- Balanced and regular meals
- Training at mid-range altitudes

Positive effects of maintaining an ideal Aerobic Readiness:

- Increased resistance to stress
- Reduced risk of overreaching and overtraining
- Increased adaptation reserves
- Decreased risk of illness and injury
- Increased work capacity

ANAEROBIC READINESS

***Anaerobic Readiness* – the current ability to perform muscle work using the glycolytic energy system while withstanding a high level of lactate in the blood.**

Training loads of an anaerobic nature are characterized by physical exercises where anaerobic glycolytic processes account for over 60% of the energy supply (for example, the 100-800m events in track & field). Mixed anaerobic-aerobic loads are considered exercises where the anaerobic and aerobic processes contribute an approximately equal amount (for example, a 1-3km run).

Anaerobic Readiness also reflects the anaerobic energy supply system's ability to compensate for an inadequacy of the *aerobic* system's energy production during strenuous muscle work.

Figure 43. Various levels of Anaerobic Readiness.

Factors which may significantly lower Anaerobic Readiness:

- Excessive load (large volume and intensity) performed using the anaerobic glycolytic system
- Lack of (or insufficient) recovery
- Unbalanced or irregular meals, particularly a lack of glycogen and protein

Risks associated with low Anaerobic Readiness:

- Reduced level of speed & power endurance
- Reduced ability to perform high intensity exercises between 0.5-2.5 minutes
- Reduced capacity of anaerobic reserves
- Reduced ability to withstand hypoxia

Factors that may increase Anaerobic Readiness:

- Regular and optimal loads of an anaerobic nature
- Customization of nutrition and supplementation

Positive effects of maintaining an ideal Anaerobic Readiness:

- Increased speed & power endurance
- Faster activation of glycolytic processes resulting in the maximal output being reached in a shorter amount of time (from 20 seconds to 5 seconds)
- Increased power and capacity of the anaerobic glycolytic system

Metabolic Reaction Index – reflects the overall effectiveness and coordination of the metabolic system to support planned training loads, measured over longer periods of time.

The Metabolic Reaction Index (MRI) characterizes the overall metabolic capacity of both the aerobic and anaerobic mechanisms of energy supply to support any kind of physical exertion. The MRI (as measured at rest), reflects the level of coordination and coherence of all mechanisms of energy supply for the realization of training (fig. 44).

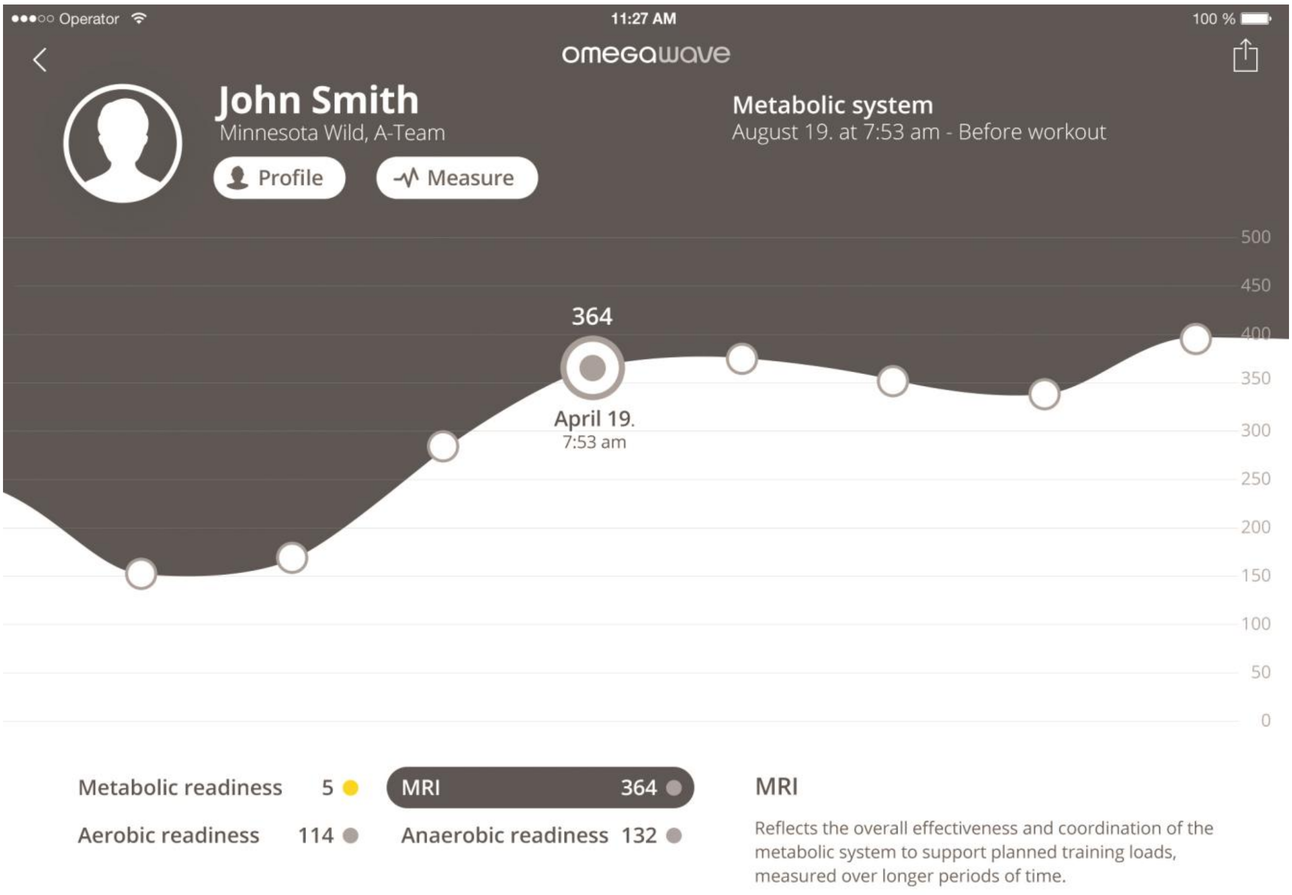


Figure 44. Various levels of MRI.

Factors that may lower MRI:

- Combination of high volume and high intensity loads of any kind
- Lack of (or inadequate) recovery
- Unbalanced or irregular meals
- Interrupted sleep rhythm or insomnia
- Illness or intoxication

Factors that may increase MRI:

- Restorative aerobic activities
- Customized recovery protocols
- Balanced and regular meals
- Return to normal sleep rhythm
- Absence of illness

Consequences of a decline in MRI over time:

- Decreased effect from recovery activities
- Decreased resistance to stress

Benefits of an increase in MRI over time:

- Increased effect from recovery processes
- Increased resistance to stress
- Increased coordination of metabolic processes

APPENDIX: THE OMEGAWAVE EXPERT SYSTEM

In artificial intelligence, an "expert system" is a computer system that emulates the decision-making ability of a human expert. The Omegawave Expert System was designed to enable coaches to effectively manage their training process based on physiological knowledge about the athlete's current functional state.

The Expert System identifies the athlete's individual biological subsystems in order to predict the athlete's overall physiological Readiness. Omegawave researched a host of elite athletes from multiple Olympic and professional sports to understand their physiological systems' (Cardiac, CNS, Metabolic, etc.) adaptational changes to various training loads. Based on this research, the predictive ability of the Expert System was created.

Various statistical analysis methods were applied to the collected data in order to create the original algorithms. These algorithms are responsible for analyzing the athlete's measurement results to provide a Readiness conclusion.

Omegawave is currently utilizing advanced artificial intelligence methods, such as Neural and Bayesian Networks, to implement self-learning capabilities into the Expert System.

The Expert System simulates the know-how of a physiology expert by looking at all of the athlete's biological indicators to give practical Readiness conclusions for optimization of the training process.

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The **Expert System** is based on the following process:

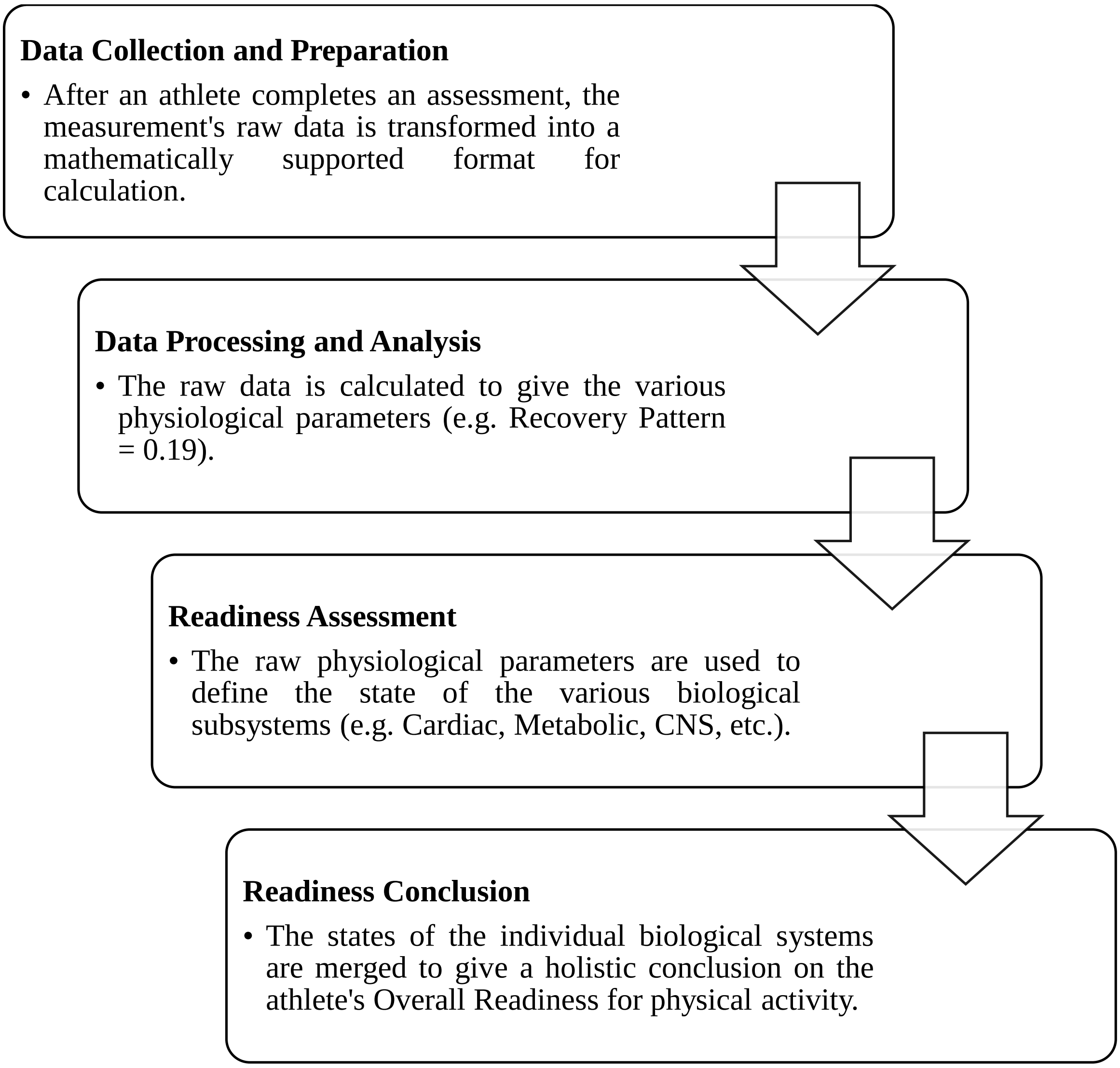

Figure 45. How the Omegawave Expert System functions.

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