Introduction

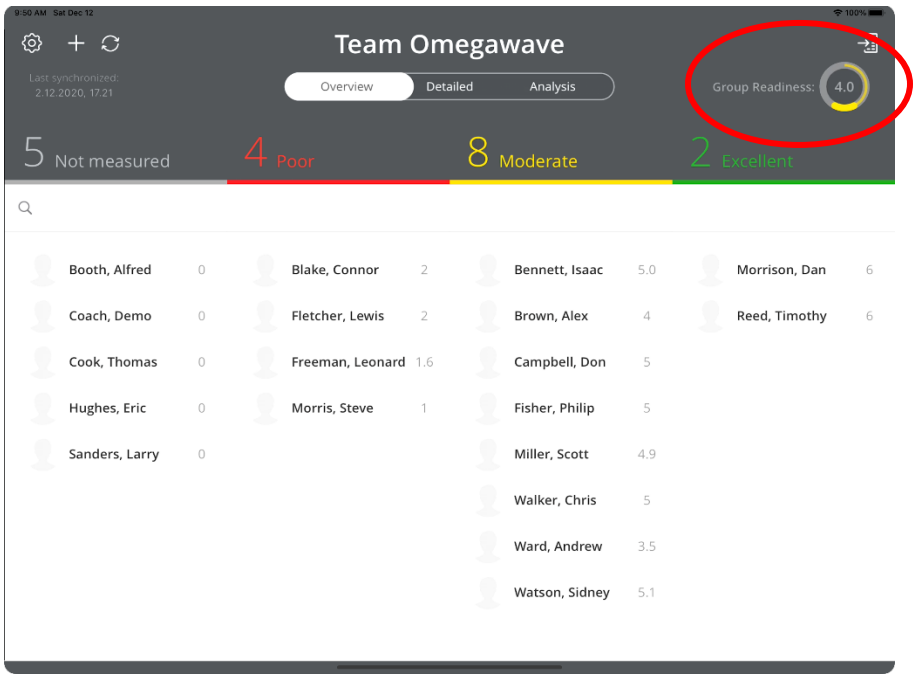
The new update comes with a few changes to the Omegawave application user interface and one major change to the DC Potential algorithm that will naturally also impact the overall Omegawave Readiness conclusion. We will discuss this algorithm change in more detail later in this document but first let's start with the user interface changes.

Group Views

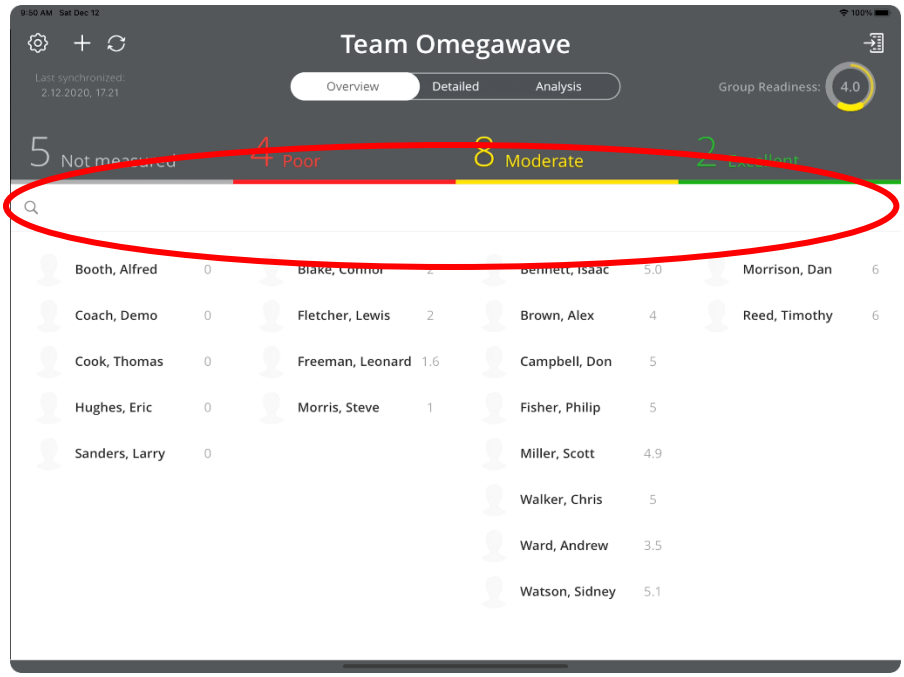
When you open the Omegawave Coach or Coach+ app, you see on top of the screen three selections: **Overview**, **Detailed** and **Analysis**.

The default screen is the **Overview**, which shows you all of the user profiles under your organization in four distinct columns: Not Measured, Poor, Moderate and Excellent. This should be familiar to you from the previous versions, but you will notice two new features on the screen:

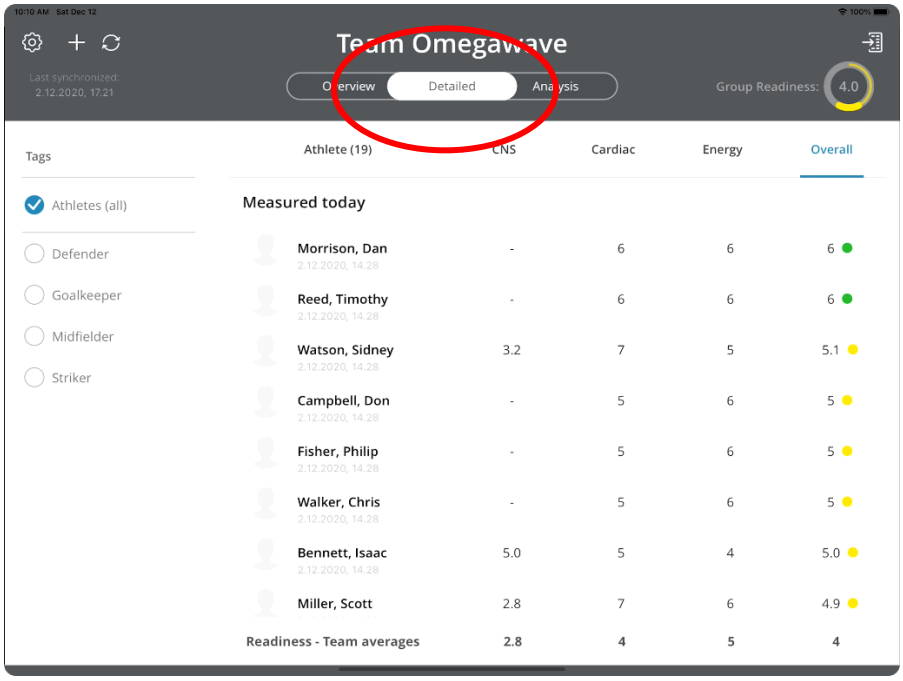
1. **Group Readiness**. This value represents the average readiness of all those individuals who have measured themselves within the past 24 hours, and thus appear on one of the three Omegawave Readiness columns: Poor, Moderate or Excellent.



2. **Search function.** You can now search for the desired user by typing in their Last name or First name into the search field.

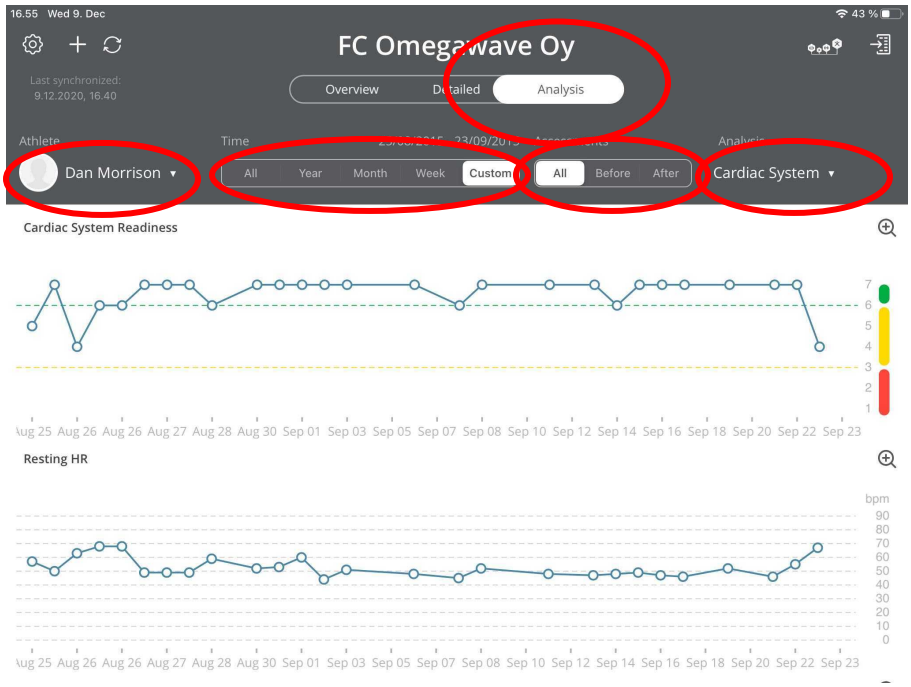


The second selection you can make to view the user profiles under your organization is called **Detailed**. This feature allows you to view each individual according to their CNS, Cardiac or Overall Readiness. This is useful, for example, when certain types of recovery or training activities are planned for the day that target more a specific biological component of the organism. An example could be cardiac output training, where cardiac system readiness is more important than CNS readiness.



The third selection you can make is **Analysis** (Coach+ only). This button will take you longitudinal analysis of a given individual. On this screen you can choose between the individual you want to analyze,

the time frame of analysis, the type of assessment included (All, Before training, After training) and finally the type of analysis parameters you want visualized in the graphs below.



Athlete/Individual view

When you click on any name/user profile in your group view, you will be taken to that individuals results. As you can see, these pages have a few visual changes to them compared to the previous app versions.

These changes you can see are:

1. **Omegawave Readiness.** The overall conclusion we gave was previously called Overall Readiness but it is henceforth called Omegawave Readiness instead.
2. **Cardiac System Readiness.** We summarized the content of what used to be on two separate screens into one screen. In other words, all ECG and HRV related information is presented on one page

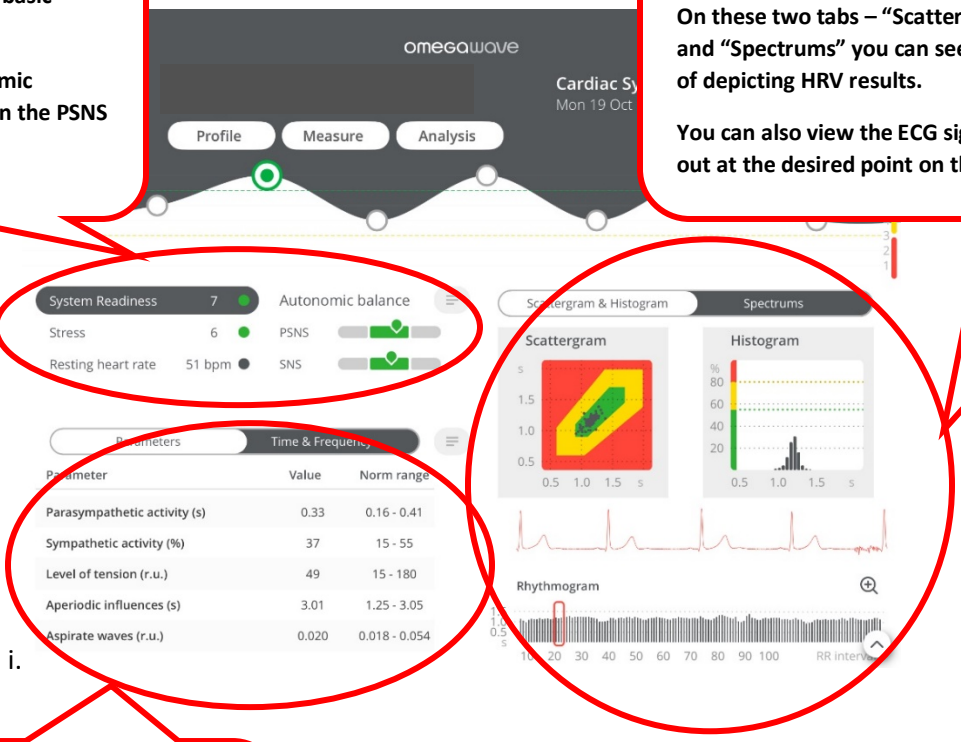
System Readiness and other basic indices of cardiac readiness.

You can also see the Autonomic Balance information graph on the PSNS (parasympathetic) and SNS (sympathetic sliders.

Spectral analysis of HRV and raw ECG curve.

On these two tabs – "Scattergram & Histogram" and "Spectrums" you can see a few visual methods of depicting HRV results.

You can also view the ECG signal and zoom in and out at the desired point on the interval.



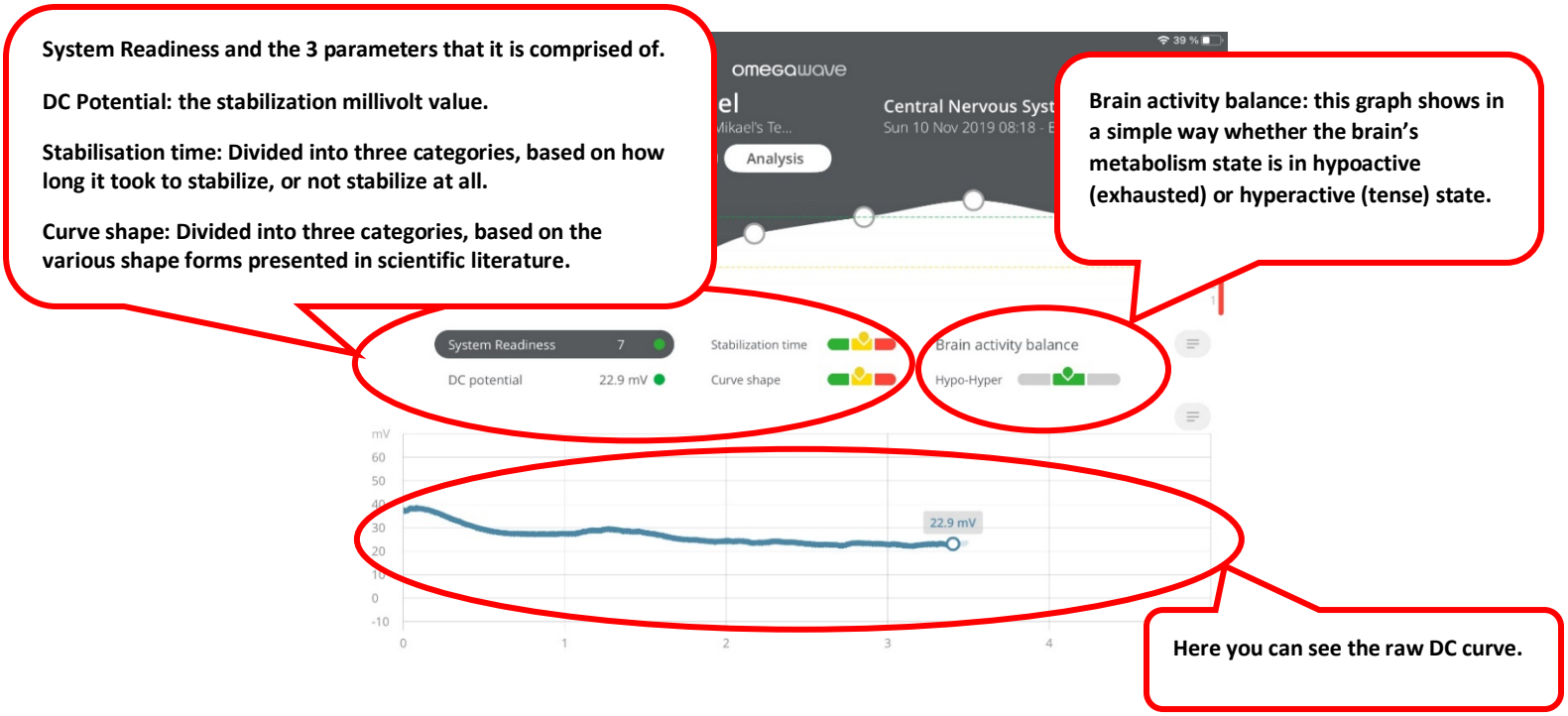
i.

Scientific parameters of HRV.

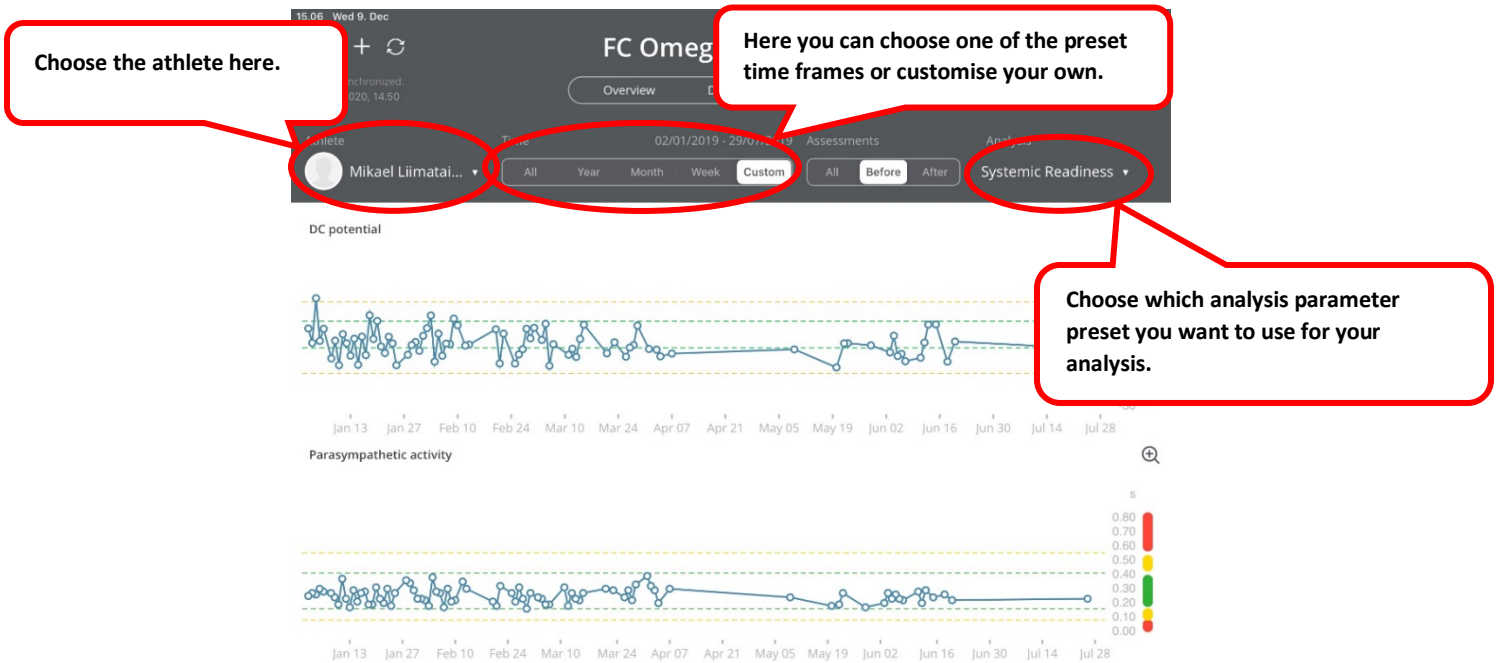
On the "Parameters" tab you can see the ones used commonly in old Russian HRV literature.

In the "Time & Frequency" tab you can see the time and frequency parameters of HRV commonly used in modern HRV literature.

3. **Central Nervous System (CNS) System Readiness.** This screen has seen a few significant changes to it, given the new DC 2.0 algorithm. The new visualization includes the following.



4. Athlete analysis. Here you can do longitudinal analysis of each individual across various DC and HRV parameters.



Introduction to the new DC Potential algorithm

The Omegawave DC Potential algorithm has undergone a vital update, where multiple parameters influence the overall outcome. Consequently, the new algorithm, and subsequently, also the Omegawave Readiness, is more sensitive to small physiological changes in the athlete. We will look at the actual changes and how the new user interface looks later but let us start with a recap basic physiology around DC and HRV and how it relates to biological adaptation, i.e., training.

Training and CNS activation

Training is a dynamic developmental physiological process aimed to form a new type of adaptations. Regular repetitions and evenly increased training intensity prompt regulatory systems to recruit additional physiological resources to create a new level of the functional state of the body. The new level of adaptation increases resistance to intense physical exertion and improves physiological and mental strength.

Sport performance is linked to the readiness of the involved biological systems (nervous, respiratory, cardiovascular, muscular, digestive, etc.) and on effective interaction between the central and the peripheral nervous systems. When the cost of doing business goes higher, the probability of performing at the peak level is also reduced.

Different methods can be applied to identify the organism's readiness, or alternatively said, biological cost. When it comes assessing this biological cost of the cardiovascular system, electrocardiography, and heart rate variability (HRV) are common methods. These methods shed more light on the state of the autonomic nervous system balance and the degree of recovery of the cardiovascular system.

On the other hand, the central nervous system (CNS) is the main coordination unit of the body that predisposes athletic performance. Adequate brain activation or arousal determines the ability of the CNS to process internal and external information and to develop an appropriate response. CNS readiness or optimal state of activation ensures mastering of technical and tactical skills, cognitive control, emotional regulation, coordination of mental and motor activity, etc.

CNS activation defines psychological preparedness and mental toughness and reflects mental fatigue state (Liew et al., 2019; Gould et al., 1987).

The CNS state assigned through analyzing of the brain electrical signals or electroencephalography (EEG), obtained from the electrodes attached to the head surface. The frequencies distributed over the head surface reflect the activation of the brain from the deep sleep to the high arousal.

More specifically, potentials in the infra slow frequency range (between 0 to 0.05 Hz), especially its negative shift or direct current (DC) potential, are related to changes in respiration, peripheral oxygenation, central and systemic hemodynamic (Aladjalova, 1957, Iluchina, 2011). Therefore, DC Potential is crucial in helping to understand the current state of readiness of an individual.

General Adaptation Syndrome and CNS

Adaptation to stress determined by an effective interaction of the organism's neuronal, cardiovascular, homeostatic (pH), humoral and endocrine regulatory systems.

The training process stimulates the development of adaptations in response to physiological or psychological stressors (general adaptation syndrome (GAS)). An intensive training load (stress) drives reorganization of the blood flow, increases muscle mass and muscle stretching, speeds up metabolic processes, stimulates immune and hormonal system and, therefore increases athlete's sports performance. At the same time, the organism has limited adaptation resources, which are needed to respond to cases of continuous or high level of stress (Selye, 1951). Hence, only optimal training load will bring a continuous improvement over time, whereas frequent as well as insufficient and non-periodic training will end up in stagnation and decline in adaptation (Cunnan et al., 2018).

Optimal training load programming should consider the information that the physiological indices obtained from HRV and CNS measurements carry. Monitoring of the organism's responses to the training process provides the possibility to validate and redesign the scheduled training routine according to the individual response to the training load.

Systemic stress response triggered by intensive training or by the internal psychological reasons is controlled by CNS. The brain is the most energy-consuming and oxygen-depended organ, and it is highly sensitive to any changes in the cerebral blood flow. Subsequently, inappropriate training load together with psychological events can deplete the brain adaptation resources, increase mental fatigue, and affect performance.

CNS System Readiness

The CNS state regulated by the reticular activation system (RAS) placed in the middle of the brain. RAS has a direct reciprocal connection with the thalamus (the main relay unit), cortical areas that provide behavior control and with the hypothalamus (the main homeostatic control unit), and is involved in the regulation of respiration, blood pressure, and cardiovascular responses. RAS regulates activation of the frontal brain areas involved in the cognitive functions (perception, attention, working memory), and at the same time, it modulates muscle tone and coordinates automatic movements, posture, etc. (Audiffren, 2016).

Moreover, an optimal cortical activation level is in turn dependent on the brain's homeostasis and metabolic balance. Managing this state ensures that the brain has the appropriate energetic resources to allow for better information processing, decision making, and performance of full range of behavioral responses.

Thus, CNS readiness is the multiparametric concept that include, on one hand, a sufficient level of physiological and psychological activation and on the other hand, a well-maintained balance of metabolic homeostasis and stress-regulation systems.

CNS readiness has been shown to be a key factor for sports performance, following a U-shape curve in performance, where activation below or higher than 60% results in decreased performance (Alert and Landers, 2003).

DC Potential (metabolic homeostasis) registered from the head surface is an integrated index that reflects the general non-specific reaction of the organism to stress and represent integration and balance within stress-regulation systems, energy homeostasis, hemodynamic and oxygenation. DC potential reflects the general level of brain activation and CNS readiness in athletes (Iluchina and Zabolotskikh, 1997). Furthermore, DC potential has also been shown to reflect the level of cortical excitability and is associated with cognitive functions: intention to act, attention, memory, preparatory set, etc. (Kort and Rix, 1979; Lang et al., 1988; Pleydell-Pearce, 1994; Vanhatalo, 2004; Ilyukhina, 2015).

DC potential dynamics and features (amplitude, form, stabilization time, etc.) represent changes in the brain's metabolic balance in response to increased exercise intensity or psychological challenges and are linked to cognitive and mental load (Iluchina, 2015, Wagshul et al., 2011).

Significant alterations in DC potential related to the decreased capacity of metabolic systems to maintain the homeostatic balance in the brain that affect cognitive and emotional control, increases anxiety and results in errors and decreased performance. (Iluchina and Zabolotskikh, 2000; Kara et al., 2020).

Following features of the DC potential were identified as significant for sport performance monitoring (Iluchina, 1986):

1. *The initial level of CNS activation –* amplitude of DC in mV (active rest condition).

This level reflects the current state of the CNS. Cerebral blood flow (CBF) and the brain metabolism in balance if and initial amplitude of DC potential stays at the range of -45 +5mV.

2. *Operational rest state* – DC amplitude after stabilization. Normal level in the range between 25 to 40 mV. “Operational rest” state is the physiological basis for mobilization, readiness and concentration.
3. *DC potential form –* DC potential form represents the dynamic interaction within stress-regulation systems. DC potential form can indicate the level of CNS activation balance, emotional stability-instability, exhaustion etc.
4. *DC stabilization speed* – measured in minutes. The spontaneous relaxation speed represents neuroreflex reactivity (neural control of baroreflex arch) of cardiovascular and respiratory systems. This measure associated with psycho-emotional dynamic and stability (Iluchina and Zabolotskikh, 1997).
    - Normal stabilization time occurs around 2 to 3 minutes and represent optimal balance within stress-regulation systems
    - Moderately slow relaxation (up to 5 minutes) reflect the slight disbalance within stress-regulation systems
    - Very slow spontaneous relaxation (up to 7-8 minutes) – significant imbalance within stress-regulation systems

These factors are now included in the new Omegawave DC 2.0 algorithm. Thus, the System Readiness on the DC Potential page and subsequently also the Omegawave Readiness conclusion on the Windows of Trainability page are the product of a multifaceted analysis of both your infra-slow brain activity and heart rate variability.

Both, high and low amplitudes of DC potential indicate decreased adaptability and an imbalance within stress-regulation systems

CNS System Readiness components

Omegawave CNS System Readiness is indicated by a floating grade from 1.0 to 7.0, where 7.0 is the optimal state.

This System Readiness index represents the state of the brain's energy level and is composed of three factors (in order of significance):

5. Stabilization point of DC potential (mV)
6. Stabilization time (reduces system readiness state of 1.0-7.0, if not optimal)
7. Curve shape (reduces system readiness state of 1.0-7.0, if not optimal)

Min[	Max]	Color
6.0	7.0	
3.0	6.0	
1.0	3.0	

Let's look at all of these three individual factors in more detail.

1. Stabilization point of DC Potential (mV)

The first priority in DC analysis is the stabilization point of DC Potential.

The stabilization values fall under three categories under the following guidelines. Please keep in mind that the real biological differences close the border values of each category are small or insignificant. In other words, an athlete with 18.1 mV and another with 17.9 mV fall under different colour categories but do not necessarily any different biological cost level. In summary, the categorization must be viewed with caution around the category border lines.

Simplified stabilization mv grade

Stabilization point	Grade
18.0 to 40.0mv	
40.0 to 56.0mv and 18.0 8.0mv	
over 56.0 and under 8.0 mv	

2. Stabilization time

The second priority of analysis is to look at the stabilization time. The impact of this factor is always negative, in other words, it will only reduce the overall system readiness state if stabilization time is lower than optimal. Please note that the strength of reduction is dependent on the first priority

(stabilization point), so that if the first factor is optimal, reduction due to slow stabilization time is higher than if first factor is already poor.

Simplified stablization time reductions

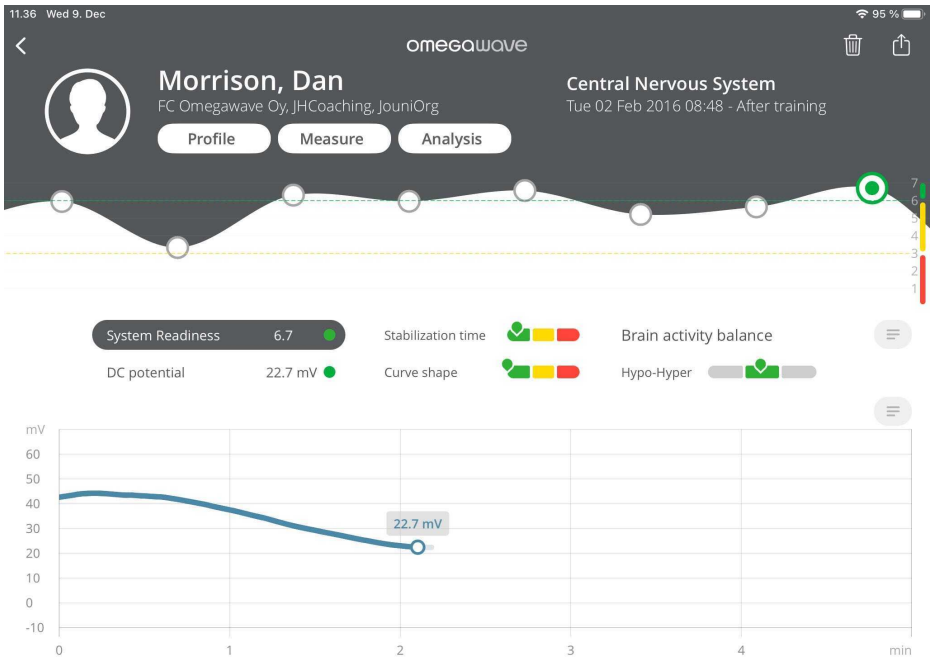
Time to stablized	Grade
Under 2min	
2minutes to 4 minutes	
4min +	

3. Curve Shape

The curve shape is composed of two elements:

- Difference between measurement start mV and end mV values
- Smoothness of the curve

The optimal shape of the curve should show a smooth transition from a higher initial value (active wakefulness) to a lower stabilization value (operational rest).

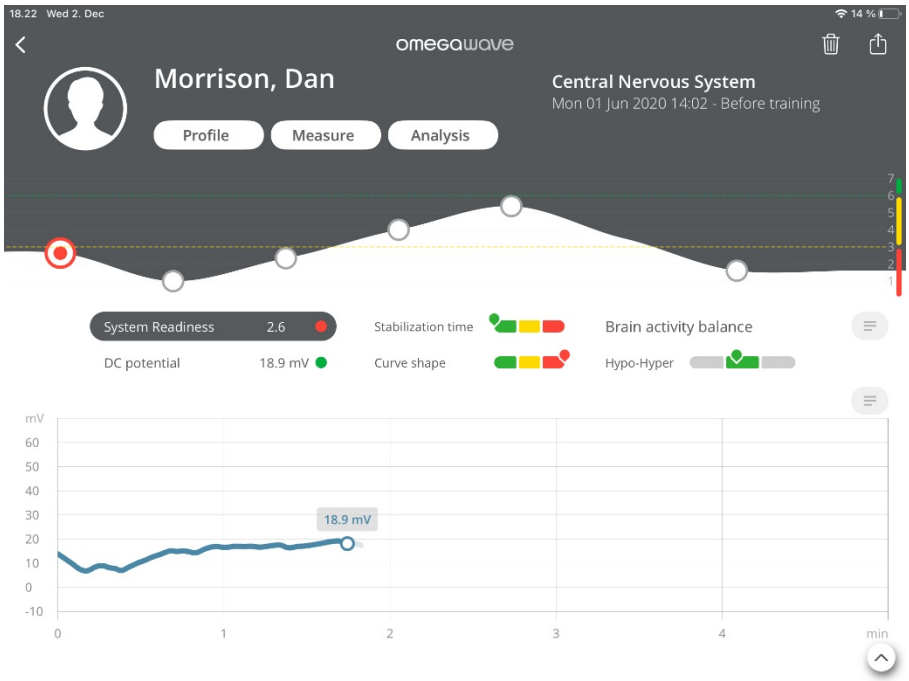


Below you can see a few examples of typical sub-optimal curve shapes. Please refer to the Coach+ application's in-app guidance for more examples. In these examples the issue causing the need for a

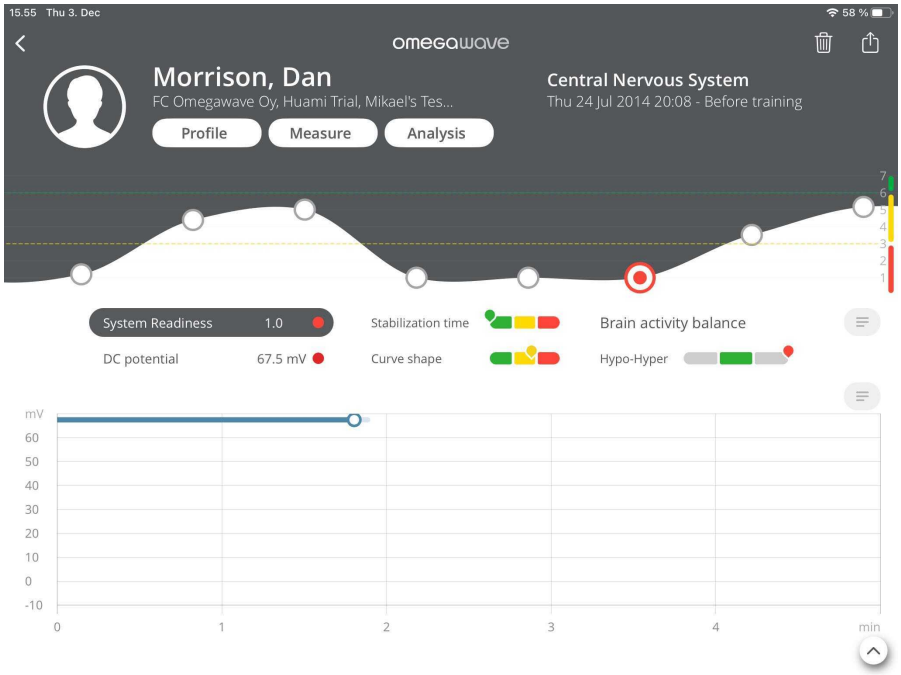
readiness reduction stems from the difference between initial and end values of the curve (in the first example, negative difference and in the second example not enough difference).

We also recognize small “bumps” in the curve shape and apply a small reduction to the overall state in this case. This reduction won’t be significant, however, if all other factors are good.

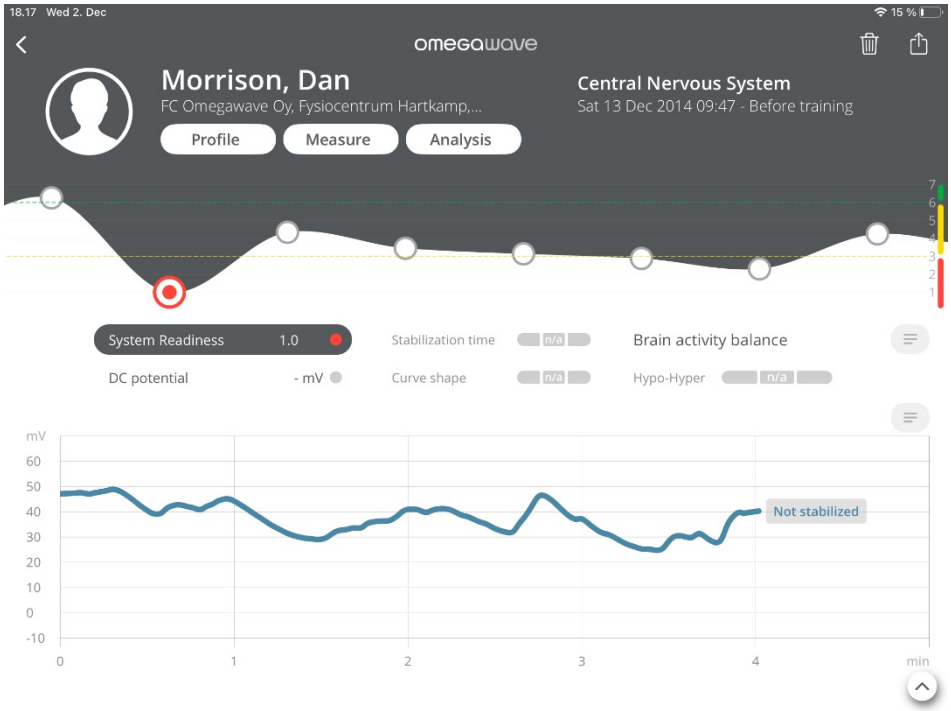
Inverted curve



Flat curve



Unstable curve



Simplified curve change mv reductions

Start-End Diff	Grade
18.0 to 45.0mv	
45.0mv to 55mv or 7.5-18mv	
below 7.5mv or more than 55mv	

References

Aladjalova N.A. (1957) Infra-slow rhythmic oscillations of the steady potential of the cerebral cortex. Nature 179:957–959, doi:10.1038/179957a0, pmid:13430746.

Arent, S. M., & Landers, D. M. (2003). Arousal, anxiety, and performance: A reexamination of the inverted-U hypothesis. Research Quarterly for Exercise and Sport, 74(4), 436-44. doi:http://dx.doi.org.libproxy.helsinki.fi/10.1080/02701367.2003.10609113

Audiffren M. The Reticular-Activating Hypofrontality (RAH) Model of Acute Exercise: Current Data and Future Perspectives. In Exercise-Cognition Interaction, chapter 7. Neuroscience Perspectives, 2016, Pages 147-166

Babiyants A. Y., Khananashvili Y. A. Brain Blood circulation: physiological aspects and modern research methods. Journal of Foundamental medicine and biology. Rostov State Medical University No. 3 2018

Branscheidt, M., Kassavetis, P., Anaya, M., Rogers, D., Huang, H. D., Lindquist, M. A., & Celnik, P. (2019). Fatigue induces long-lasting detrimental changes in motor-skill learning. eLife, 8, e40578. https://doi.org/10.7554/eLife.40578

Carter J.B., Banister E.W., Blaber A.P. Effect of endurance exercise on autonomic control of heart rate. Sports Med. 2003;33(1):33-46.

Cunanan, A.J., DeWeese, B.H., Wagle, J.P. et al. The General Adaptation Syndrome: A Foundation for the Concept of Periodization. Sports Med 48, 787–797 (2018). https://doi.org/10.1007/s40279-017-0855-3

Gould D., Hodge K., Peterson K., & Petlichkoff L. (1987). Psychological foundations of coaching: Similarities and differences among intercollegiate wrestling coaches. The Sport Psychologist, 1(4), 293–308. https://doi.org/10.1123/tsp.1.4.293.

Iluchina V.A. Contributions of Academicians A.A. Ukhtomsky and N.P. Bechtereva to Multidisciplinary Human Brain Science. Cognitive Systems Monographs 25:81-100. July 2015. DOI: 10.1007/978-3-319-19446-2_5

Ilyukhina V.A. Continuity and development prospects of research in the field of system-integrative psychophysiology of functional states and cognitive activity // Human Physiology. 2011.V. 37. No. 4. P. 105.

Ilyukhina, V.A., Zabolotskikh, I.B. Physiological basis of differences in the body tolerance to submaximal physical load to capacity in healthy young individuals. Hum Physiol 26, 330–336 (2000). https://doi.org/10.1007/BF02760195

Ilyukhina, V.A. and Zabolotskikh, I.B., The Typology of Spontaneous and Induced Dynamics of Superslow Physiological Processes Recorded from the Surface of the Head and the Body of a Healthy and Sick Man,Kuban Med. Vestn., 1997, no. 4, p. 12.

Ilyukhina V.A. Neurophysiology of human functional states. L., Science, 1986, 171 pp.

Kara O.V., Polo O. (2014). Autonomic and central stress-regulation disintegration in stress-related anxiety disorders. Acta Neuropsychologica 12(1):1-25

Kara O.V., Starchenko M.G., Boytsova J.A., Panteleeva G.V., Voronov I.A. (2020). Analysis of relationship between the level of anxiety and function of anticipation, subjective assessment of one's own psychological and physical condition and balance of the autonomic nervous system among sportsmen. Uchenye zapiski universiteta imeni P.F. Lesgafta, 1 (179), 406-411.

Korth M., Rix R. (1979). The influence of vigilance on DC response in human visual evoked potential (author's transl). Albrecht Von Graefes Arch Klin Exp Ophthalmol; 2;210(2):141-50.

Kreher, J. B., & Schwartz, J. B. (2012). Overtraining syndrome: a practical guide. Sports health, 4(2), 128–138. https://doi.org/10.1177/1941738111434406

Lang W., Lang M., Uhl F., Koska C., Kornhuber A., Deecke L. (1988). Negative cortical DC shifts preceding and accompanying simultaneous and sequential finger movements. Exp Brain Res.;71(3):579-87.

Liew G.C., Kuan G., Chin N.S. et al. Mental toughness in sport. Ger J Exerc Sport Res 49, 381–394 (2019). https://doi.org/10.1007/s12662-019-00603-3

Martin K, Meeusen R2 Thompson KG, Keegan R, Rattray B. Mental Fatigue Impairs Endurance Performance: A Physiological Explanation. Sports Med. 2018 Sep;48(9):2041-2051. doi: 10.1007/s40279-018-0946-9.

Ogoh S, Ainslie PN. Regulatory mechanisms of cerebral blood flow during exercise: new concepts. Exerc Sport Sci Rev. 2009 Jul;37(3):123-9. doi: 10.1097/JES.0b013e3181aa64d7.

Pleydell-Pearce C.W. (1994). DC potential correlates of attention and cognitive load. Cognitive Neuropsychology; 11(2):149-166.

Raley-Susman KM, Cragoe EJ Jr, Sapolsky RM, Kopito RR. Regulation of intracellular pH in cultured hippocampal neurons by an amiloride-insensitive Na+/H+ exchanger. J Biol Chem. 1991 Feb 15;266(5):2739-45.

Rohlfs, Izabel Cristina Provenza de Miranda, Mara, Lourenço Sampaio de, Lima, Walter Celso de, & Carvalho, Tales de. (2005). Relationship of the overtraining syndrome with stress, fatigue, and serotonin. Revista Brasileira de Medicina do Esporte, 11(6), 367-372. https://doi.org/10.1590/S1517-86922005000600012

Selye H. The general-adaptation-syndrome. Annu Rev Med. 1951;2:327-42.

Schiphof-Godart, L., Roelands, B., & Hettinga, F. J. (2018). Drive in Sports: How Mental Fatigue Affects Endurance Performance. Frontiers in psychology, 9, 1383. https://doi.org/10.3389/fpsyg.2018.01383

Schmidt SL, Schmidt GJ, Padilla CS, Simões EN, Tolentino JC, Barroso PR, Narciso JH, Godoy ES and Costa Filho RL (2019) Decrease in Attentional Performance After Repeated Bouts of High Intensity Exercise in Association-Football Referees and Assistant Referees. Front. Psychol. 10:2014. doi: 10.3389/fpsyg.2019.02014

Thomas, A. G., Dennis, A., Bandettini, P. A., & Johansen-Berg, H. (2012). The effects of aerobic activity on brain structure. Frontiers in psychology, 3, 86. https://doi.org/10.3389/fpsyg.2012.00086

Vanhatalo S., Palva J.M., Holmes M.D., Miller J.W., Voipio J., et al. (2004) Infraslow oscillations modulate excitability and interictal epileptic activity in the human cortex during sleep. Proc Natl Acad Sci U S A 101: 5053–5057

Zając, A., Chalimoniuk, M., Maszczyk, A., Gołaś, A., & Lngfort, J. (2015). Central and Peripheral Fatigue During Resistance Exercise - A Critical Review. Journal of human kinetics, 49, 159–169. https://doi.org/10.1515/hukin-2015-0118