Omegawave Sport Technology® - New Ways of Performance Diagnosis

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Abstract

The Omegawave Sport Technology® System promises a non-invasive, accurate evaluation of physical functional state in seconds. On the basis of determining heart rate variability, a differential ECG and measurement of slow cortical potential shifts, the system derives details on aerobic and anaerobic capacity, the vegetative and central nervous system and the hormonal status of the athlete. In view of the increasingly widespread use of this system, this article will explain the fundamental measurement techniques of Omegawave and discuss the information derived from them, against the background of scientifically proven results.

Keywords

Omegawave, heart rate variability, differential ECG, omega potential

Introduction

The accurate evaluation of physical functional state in seconds and of the instantaneous degree of regeneration or load capacity using a non-invasive method of examination is what athletes, trainers and medical support staff have long been waiting for. Traditional methods of performance diagnosis are based on a direct examination of cardiorespiratory function and muscular and metabolic parameters. However, these tests are frequently costly and time-consuming, so that in many cases it is almost impossible to integrate them on an ongoing basis into the training process as a control measure.

The Omegawave Sport Technology® System (Omegawave Technologies, Portland OR, USA) is based on up to eight different test methods, which according to the manufacturer enable conclusions to be drawn about all systems involved in physical capacity. The prospect of having permanent access to information on aerobic and anaerobic capacity, the vegetative and central nervous system and the hormonal status of the athlete is highly attractive and has already convinced a good many highly reputable sports organisations, associations and clubs. However, only a small number of scientific publications on this system have appeared, so an attempt at serious, objective validation is now due.

The aim of this examination is, therefore, to present the Omegawave Sport Technology® System and to discuss its functional principles. The focus will be on a description of the three most important test methods, the information derived by the system and a discussion of this information in the context of scientifically proven findings.

Heart rate variability

Heart rate variability (HRV) refers to the characteristic of the (healthy) human heart to vary its rate spontaneously. For investigative purposes, in the simplest case, the intervals between the individual QRS complexes in the ECG image, the so-called normal-normal (NN) intervals, are collected and the HRV is expressed as a statistical value of the data thus collected (33). In addition to this time index of the HRV, spectral analysis (power spectral density, PSD) provides an opportunity to characterise fluctuations in heart frequency in more detail. It is designed to use a mathematical algorithm (fast Fourier transformation) to extract, from the temporal sequence of depolarisations of the sinus node, the rhythms embedded therein and to represent them as a function of frequency (6).

In principle, four frequency ranges of the HRV can be identified: high frequency (HF) in the range from 0.4-0.15 Hz, low frequency (LF) from 0.15-0.04 Hz, very low frequency (VLF) from 0.04-0.003 Hz and ultra-low frequency (ULF) with frequencies less than 0.003 Hz. The prevalence of the individual frequencies is usually stated as the absolute value of their power (ms^2). Their ratios relative to total variability are referred to as normalised units (n.u.) of power. Figure 1 shows the PSD frequency range of a test subject in supine position and after changing physical position.

portion of the spectrum and parasympathetic activity (42). The low-frequency components are disputed and tend to be ascribed to sympathetic control (cf. Review by Achten and Jeukendrup (1)). Accordingly, some authors interpret the LF:HF ratio as an expression of the sympathicovagal balance, although this is still disputed (33), since it has been shown that the LF frequency range reacts both to blockade of the sympathetic and of the vagal branch of the autonomous nervous system (42).

The HRV is partially explained in this case by respiratory sinus arrhythmia. Shorter or longer NN intervals appear as a function of inhalation and exhalation, which is attributed to the vagal influence on the heart (34). Further major determinants of HRV have been identified as age and sex (22), and, in connection with the baroreflex, body position (38).

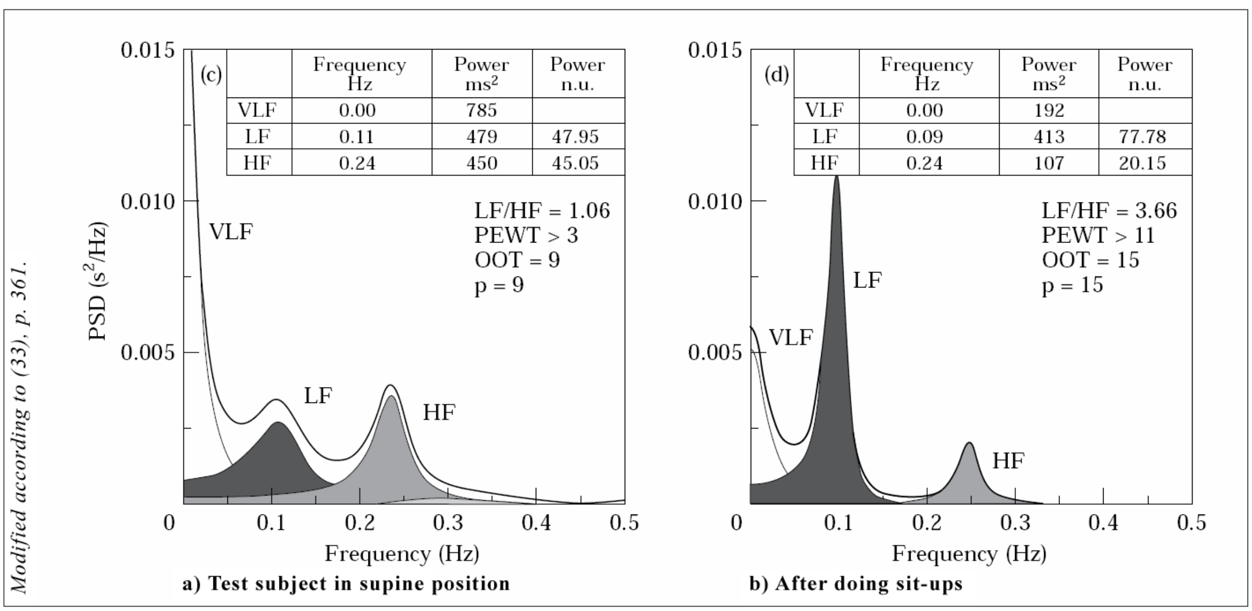

Figure 1: Spectral analysis (PSD) of HRV

The peaks in the frequency spectrum represent the influence of the parasympathetic and the sympathetic branch of the autonomous nervous system (23). Both clinical and experimental studies have shown an association between the HF

In clinical practice, PSD has, for some years now, been used in the risk stratification of sudden cardiac death (24) and diabetic autonomic neuropathy (26). However, more recently sports sciences have also recognised HRV as a parameter for physical stress and potential control parameter for exercise intensity. The sympathetic nervous system activity which progressively increases in line with simultaneous vagus inhibition, is evidence of the importance of the autonomous nervous system to the control of physiological reactions to acute load states. A change in HRV as a function of the type, amount and intensity of the exercise stimulus is therefore expected (37). The study findings in this respect, however, do not show a completely uniform picture. There is widespread agreement about the statement that the total variability of heart rate and thus absolute powers in the HF and LF range reduce with increasing exercise intensity (cf. Review by Hottenrott, Hoos and Esperer (16)). The anticipated increase in LF:HF quotients could not be proven in all studies. The investigations into relative powers in these frequency ranges arrived at extremely divergent results, which extend from a rise in the LF portion, via extensive constancy of the LF:HF quotient, to a rise in the HF portion. The relevant reviews by Hottenrott et al. (16), Aubert, Seps and Beckers (2) and also Achten et al (1) provide a good overview. In particular at exercise intensities > 70% of maximum oxygen uptake (VO_2 max), HRV is doubtful as a reliable marker of autonomous regulation of cardiac function (7); (13); (40). Consequently the interpretation of HRV appears to be useful in the case of primarily aerobic energy provision. Aubert et al. (2) attribute the inconsistency in available information to varying investigation designs and exercise parameters. HRV is thus in principle accepted as a marker of the instantaneous degree of stress of the cardiovascular system. Future studies should be aimed at the development of a standardised protocol, the expression of HRV in standard values (time or frequency indices) and the derivation of corresponding reference values for cohorts defined according to age, sex and training condition.

If HRV is tested as a potential predictive factor of physical capacity, it is important to confirm the adaptive reactions to which it is subject in the long-term training process. Training in the endurance range leads to sinus bradycardia in resting condition and to a slower rise in heart rate at sub-maximum exertion. This shift of the sympathicovagal balance towards the parasympathetic has already been proven several times in the latest publications (21); (35). Accordingly, in connection with moderate endurance training, an increase in the HF portions and simultaneous decrease in the LF portions and a general increase in HRV (total power) has been proven (12); (30); (45). It is disputed whether endurance training can provoke changes in the HRV in endurance training in old age, too (39). In complete contrast to moderate endurance training, excessive endurance training such as cycling's Tour of Spain (9) was accompanied by a general decrease in HRV (in time and frequency parameters) and a reduced resting heart rate. Hottenrott et al. (16) interpret this as the expression of saturation behaviour of the sinus node relating to the autonomous regulation of the heartbeat, due to a drastic increase in the efferent vagus activity. HRV appears to be largely insensitive to strength and strength-endurance training stimuli (11); (25). To summarise, it can be concluded that HRV does not respond uniformly to training stimuli, but the corresponding adaptations depend to a large extent on exercise parameters and individual factors, such as training level and biological age (16).

The diagnostic value of HRV with respect to the recognition of a case of over-training, as propagated by various studies (14); (17); (32), was recently evaluated by Bosquet, Mekari, Arvisais and Aubert (5). The meta-analysis, which took into account 34 studies of high-performance athletes with above-average training loads, showed a slight increase in the LF:HF quotient as a reaction to short-term (< 2 weeks) over-training, with an insignificant decrease in total HRV. The adaptations to longer training interventions did not attain any statistical significance. It can, therefore, be concluded that HRV could be used to detect acute fatigue, but not chronic overtraining. However, if one accepts the underlying hypothesis that all athletes taken into account in this review were, in fact, overtraining in some way, and in view of the varying forms of loading, the unequal boundary conditions and the comparatively small cohort, the validity of the study, as the authors themselves emphasise, is limited. The HRV changes observed were also slight to moderate in all cases, so they could also lie within the range of normal daily fluctuations. The authors, therefore, rule out HRV as sole predictor of overtraining for the time being and recommend further studies using standardised exercise protocols and boundary conditions.

Signal-averaged echocardiography

Signal-averaged echocardiography (SAECG) represents a technique for processing echocardiograms based on improving the signal-noise ratio and averaging of consecutive QRS complexes. In the clinical domain, it is used to diagnose ventricular late potentials (fractionated low amplitude fluctuating repolarisations), which are useful as indicators of tachyarrhythmias following ischaemic tissue damage. Three parameters are regarded as generally accepted in this instance (see Fig. 2): 1. the duration of the QRS complex (QRSd), 2. the duration of the terminal, low-amplitude (<40 μV) signal (LAS40) and 3. the average signal amplitude of the last 40 ms of the QRS complex (RMS40) (10). At a filter frequency of 25 Hz, a QRSd > 120 ms, an RMS40 < 25 μV and an LAS40 >38 ms represent the criteria of pathological findings.

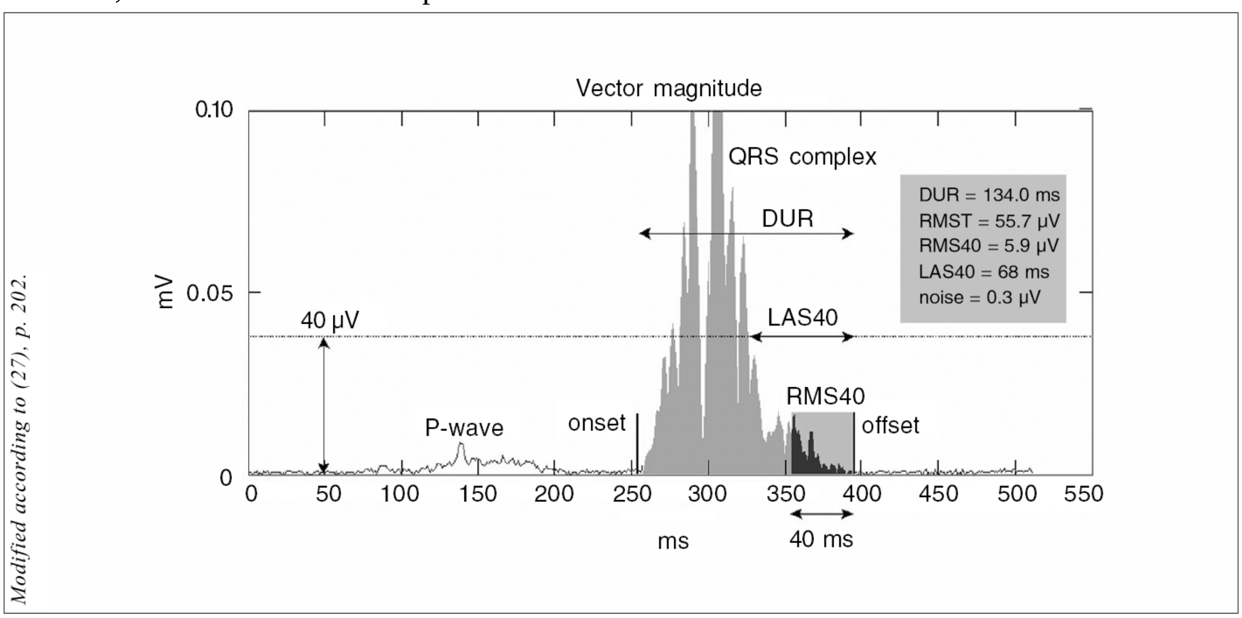

Figure 2: Signal-averaged echocardiography (SAECG)

In the context of sports science, SAECG was originally used to assess the mass and volume of the left ventricle, whereby the calculation of the integral under the whole QRS complex and thus consideration of the full QRSd proved to be the method with the greatest validity (46); (36). Nevertheless, correlations between SAECG parameters and left-ventricular mass are not undisputed. Biffi, Verdile and Ansalone (4) found no connection whatsoever with a QRd > 114 ms. Other studies have attempted to produce a substantive connection between the presence of ventricular late potentials (LP) and endurance training. Smith, Vacek, Wilson, Hawkins and Boyer (44) observed an improvement in SAECG parameters, characterised by a decrease in QRSd with simultaneous increase in RMS40, immediately after the end of a marathon run. Marocolo, Nadal and Barbola (27) found an equally improved SAECG image in their comparison of endurance-trained athletes (24 h after training) with a healthy, untrained control group. In contrast, other studies presume a higher incidence of LP in chronic and acute endurance-trained athletes, which are interpreted as a sign of fatigue of the myocardium and as a risk factor for sudden cardiac death. The relevant findings are, however, not unequivocal. Warburton et al. (52) found no significant differences relating to QRSd and LAS40 before, directly and 24 - 48 h after a half-ironman race. They nevertheless emphasise that, in two of the nine athletes examined, SAECG anomalies were found even before the competition, which were even more marked immediately after the competition. A subsequent study on a female-only cohort showed similar results (51).

Moroe, Kimoto and Inoue (31) examined just under 800 athletes using SAECG and found an increased incidence of related anomalies in those test subjects who train mainly in the anaerobic range. The authors attributed this to deterioration in the electrical conductivity of the strength-trained heart.

Marcolo et al. (27) went even further in their efforts for a performance physiological interpretation of SAECG parameters. They studied 18 endurance runners specialising in long distances and a control group of the same size, determining their HRV and SAECG parameters, and correlated the measurement values thus found with the maximum oxygen uptake, estimated by a 12 min Cooper test (VO_2 max). There were strong positive correlations between the average signal amplitude of the total QRS complex (RMST) and the RMS40 and VO_2 max respectively and also a weaker, negative connection with LAS40. The RMST was hereby recognised as the sole independent predictor of VO_2 max. The authors therefore conclude that ventricular adaptation reactions to endurance training are expressed in the SAECG image and this is therefore a potential marker for the aerobic performance capacity of an athlete.

Omega Potential

The capture of central nervous processes has only very recently been recognised as a source of information for the evaluation of sporting performance capacity. As the bioelectric equivalent of cortical activity, the spontaneous topographical encephalogram (EEG) was introduced into sports medical practice (29). By using electrode caps specifically designed for sporting activity, it is now possible to assess exercise-induced changes in the cortical functional state with sufficient spatial resolution (see e.g. Review by Crabbe, Dishman and Brain (8)). Apart from the differentiated frequency spectrum normally used in the EEG, from delta (03 - 3.5 Hz) to beta waves (14-30 Hz), slow variable cortical potential shifts (SP) were recorded as long ago as the nineteen sixties. The term direct current potential is based on the especially slow voltage shifts, not detectable in the normal EEG (by definition, ≤ 0.2 Hz) and is physically not correct.

Despite the somewhat controversial debate concerning the origin of the SP (48), it is regarded as largely established that slow potential shifts represent the neurophysiological correlate of different layers of consciousness (53); (28). Significant SP shifts have also been observed in epileptic seizures (47), as the result of fluctuations in CO_2 partial pressure in the cerebral blood vessels (50) and spontaneously in premature babies (49). The connections of the SP with cognitive tasks (41); (3) are also well documented.

In the context of sports, the slow bioelectrical activities of the brain have been dealt with mainly in untranslated Russian publications (43); (18), the findings of which cannot be taken into account in the present work. Ilyukhina and colleagues introduced the term omega potential in their works (19); (20) to refer to ultra-slow SP, with a constancy of between one and several minutes. On the basis of their empirical research on 2,900 healthy athletes, and on 1,200 patients suffering from various clinical pictures undergoing in-patient treatment, the authors postulated a direct link between changes in the omega potential and chemical-metabolic, neuro-humoral and endocrine reaction processes under physical stress. Functional statements were derived from the percentage deviations in the omega resting potential about the central nervous system, the cardiorespiratory system, the body's own detoxifying processes and the hypothalamic-hypophysary-adrenal system. The authors continue by saying that the spontaneous shifts in the omega potential at rest and the deviations under sporting exertion followed specific patterns, the contents of which have been used to interpret the actual physical capacity and learning capacity of the athlete.

Discussion

HRV is the central measurement value of the Omegawave system. Based on a 3-electrode lead, over either five or ten minutes, time and rate-related parameters are calculated and placed in relation to the system's own normal values. The HF portions of the frequency spectrum are interpreted as a measure of the vagal, the LF portions as a measure of the sympathetic influence on the heart rhythm. The VLF components, on the other hand, are ascribed to central nervous control processes which, according to the manufacturers, successively take over the regulation of the heartbeat as the intensity of exercise increases. At this point the system generates a report on the type of heart rhythm (bradycardia, normocardia or tachycardia), its regulation mechanisms, the sympatheticovagal balance and the instantaneous loading condition of the heart. These details are then integrated in an assessment of the current load capacity of the cardiovascular system.

The interpretation of the HF portion of the frequency spectrum in the sense of vagal influence on heart rate corresponds to the present state of knowledge (42). Although proclaimed by many studies the interpretation of the LF components as parameters of sympathetic activity is, however, not undisputed (1). These doubts are based on study findings which showed that the LF frequency range reacts to blockade of both bundle-branches of the autonomous nervous system (42). To this extent, statements on the vegetative balance based on the LF:HF ratio require additional corroboration by further-reaching studies. Nor, to date, has the postulated connection between VLF portions and the central nervous system been confirmed. It is presumed that there are dependencies of various factors, such as thermoregulatory processes, vasomotor and hormonal influences and the function of the renin-angiotensin-aldosterone system (15), so that single-factor interpretations, in particular in the case of short-term recordings, are not advisable (33).

The manufacturer emphasises that training-related statements cannot be made on the basis of one-off measurements, but only by long-term continuous checks. Within the framework of a moderate endurance training regime, a largely uniform adaptation picture has been recognised with respect to HRV. This includes a rise in the HF portions with simultaneous decrease in LF components and a rise in total power (12); (30); (45). Accordingly, the use of Omegawave appears highly promising in the assessment of performance in endurance training. There are fewer reports on the effects of excessive endurance training in top-ranking sports (cycle tours, triathlon, etc.) (9), but these appear in principle to provoke different HRV reactions (reduction of total power).

The extensive absence of HRV adaptations due to strength and strength-endurance training (11); (25) underlines the fact that the anticipated HRV changes depend heavily on the nature, intensity and extent of the exercise stimulus taking effect. Hence the use of data on heart rate variability with a view to managing training requires a precise and complete set of training documentation, as well as knowledge of typical HRV reaction patterns.

The differential ECG of the Omegawave System includes four extremity- and three chest wall leads. Depending on the selected recording time of the HRV, the differential ECG is also recorded for five or ten minutes. The hypothesis is generally accepted that there is a connection between the depolarisation patterns of both ventricles and various energy supply mechanisms. So indices for maximum oxygen uptake and the functional capacity of the aerobic, anaerobic and alacticide system and the heart rate in various ranges of intensity are calculated. According to the manufacturer, empirical data shows high correlations with VO_2 max (0.83), heart rate at the (not defined more precisely) anaerobic threshold (0.71) and the functional capacity of the alactacide system (0.60). The indices ultimately lead to the specification of exact heart rate ranges for training in various intensity ranges.

Vacek, Wilson, Botteron and Dobbins (46) and also Okin et al. (36) postulated a connection between SAECG parameters and the mass and/or volume of the left ventricle. If one assumes an increased stroke volume in the frame of an eccentric hypertrophy of the myocardium in endurance-trained athletes, statements about aerobic capacity appear plausible. These findings were, however, later partly revised by Biffi et al. (4). The soundest indications so far are supplied by Marocolo et al. (27), which correlated the SAECG data with the VO_2 max estimated by a Cooper test. Their findings (correlation with the RMST at 0.77) appear highly promising. Further studies on larger cohorts and with simultaneous direct measurement of VO_2 max are, however, necessary.

Moroe et al. (31) found resting SAECG anomalies in 8.5% of their test subjects and noted a connection with a lower than average mass of the left ventricle. These anomalies, according to the authors, occurred more often in mainly anaerobically-training athletes. The size of the cohort studied here supports the hypothesis that there is a link between the SAECG image and the anaerobic capacity.

According to our state of knowledge the studies cited in this analysis reflect, the currently proven state of information in relation to the connection between metabolic processes in the skeletal muscle and electrical activities in the heart muscle. The relatively low number of publications is explained by the newness of the system. Although the works tend to support an existing relationship between energy supply and differential ECG image, the tremendously general and explicit nature of the statements derived by Omegawave appear to require further studies on larger cohorts. These should particularly include comparisons of ECG data with results from lactate-performance diagnosis and spiroergometry.

The electrical activities referred to by Ilyukhina, Sychev, Shcherbakova, Baryshev and Denisova (20) as omega potential refer to the ultra-slow potential shifts in the cortex measured by the system. When measuring using Omegawave, two additional electrodes, one on the forehead and the second on the ball of the thumb, are attached to the test subject. Firstly, in supine position, a resting potential is determined, which is divided according to its voltage into four categories (very low, low, optimal, high). The completion of this process, which takes about seven minutes, is marked by an acoustic signal. At this point, the test subject is asked to perform two sit-ups. The omega potential, now affected by the physical activity, is recorded for a further seven minutes and interpreted as a function of time and voltage. In this way the functionality of the central nervous system, the gas exchange system, the body's own detoxification systems and the hypothalamic-hypophysary-adrenal system is assessed.

The existence and physiological relevance of slow cortical potential shifts has been sufficiently studied and is now regarded as proven. In the context of sports science, the works of Ilyukhina et al. (19); (20) form the sole basis for evaluation of the validity of the omega potential. They integrated their studies on a total of over 2,900 athletes into the existing findings on SP from clinical practice and concluded that the omega potential functions as the body's general control equipment. Like a universal language, it controls bodily functions at rest and under physical exertion. The neurohumoral interaction between CNS and the effector organs is, the authors continue, the mechanism underlying this. Despite the early commitment in the former Soviet republics, research into slow cortical potential shifts has not so far further increased among the sports science community. The fact that perhaps fluctuations in the CO_2 partial pressure in cerebral vessels (50) or cognitive tasks (41); (3) correlate with SP shifts does, however, make opportunities for sports scientific interpretation appear plausible. Further research and the inclusion of independent test methods to determine lung function and hormone status are also needed in this area.

The Omegawave Sport Technology® System, with its completely non-invasive test methods, is exploring new avenues in performance diagnosis. The innovative nature of the approach is reflected in the as yet incomplete scientific reappraisal of the underlying functional principles. At present, the Omegawave statements relating to one-off measurements must be critically discussed. However, in the context of intra-individual continuous controls, the performance physiological interpretation of data on heart rate variability, echocardiograms or slow cortical potential shifts appears to be highly promising. The strengths of the system lie in the rapid availability of data, the relative cost effectiveness, and the coverage of areas on which no, or only indirect, statements could be made with conventional test systems. Omegawave cannot, therefore, replace, for example, ergometric stage tests, the precision of which cannot be achieved when determining the heart rate in different training areas by any indirect measurement method. The longer-term observation of the Omegawave data could, however, assuming appropriate knowledge of the underlying functional principles, make a significant contribution to an understanding of the current training- and/or load capacity of the athlete. To this extent, Omegawave has already been introduced by some of the greatest football clubs in the world, such as A.C. Milan, Bayern Munich, FC Barcelona and Manchester United. Future scientific discussions should focus on the documentation of data in long-term training studies on larger cohorts.

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