Electroencephalogram Analysis of Athletes with Over-training Syndrome

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ABSTRACT

When the athletes' fatigue produced in training and competition process is accumulated continuously, their bodies will appear function disorder or pathological condition, medically called overtraining syndrome. When athletes are engaged in sports activities, which are based on the stretching of muscles, but the muscle movement is controlled and regulated by the central nervous system, and at the same time, the physiological action of the central nervous system will reflect on the Electroencephalogram (EEG) signals. Therefore, this study focuses on the EEG of athletes with overtraining syndrome. The differences and similarities of EEG of 100 patients with overtraining syndrome are recorded and compared with each other, with the data of 100 healthy athletes as control. In each of the patients studied, there is a decrease in sustained motor capacity, with different degrees and signs. It is expected to apply EEG knowledge to select materials and guide sports training for guidance and reference.

Key Words: EEG, Over-training Syndrome, Abnormal Diffuse, Scattered Slow Wave

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Introduction

Fatigue caused by overtraining leads to excessive tension in the normal activity process of cerebral cortex, so the pathological basis of overtraining syndrome is not the pathological changes of physiological structure, but the dysfunction of nervous system. According to the degree of exercise fatigue, overtraining can be divided into short-term overtraining and overtraining syndrome. Overtraining, which takes place in a short term, is called overwork, which can be easily restored in a few days. Continuing to try is often part of many training programs. Overwork theory is based on overwork (reducing athletic performance and stamina), and then the athletic performance gradually bounces back. Thus, studies have shown that short-term overwork caused by re-bounce can increase strength and explosive force (Lehmann *et al.*, 1993). If the sustained overwork exceeds a reasonable duration, it can become an overtraining syndrome, which is derived from overtraining, and it is sometimes referred to as fatigue.

Formation mechanism of overtraining

The formation mechanism of overtraining is shown as in figure 1.

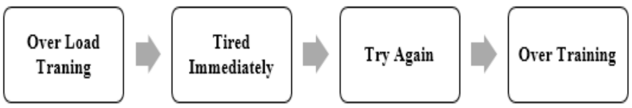

Figure 1. Formation mechanism of overtraining

Classification of symptoms in overtraining

Sympathetic and parasympathetic nervous syndrome. Sympathetic nerve syndrome refers to an increase in sympathetic nerve activities during rest, while parasympathetic nerve syndrome involves an increase in parasympathetic nerve activities during rest and exercise.

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Exactly the last time of overtraining is likely to be caused by parasympathetic nerve syndrome (Anderer *et al.*, 1994).

Four stages and symptoms of overtraining performance

Stage I: Without effect on motor performance, the function of neurons begins to change;

Stage II: With little or no effect on motor performance, motor unit recruitment begins to change;

Stage III: Exercise realization may decrease, the nervous system may reduce the regulation of exercise, the skeletal muscle excitement begins to change, muscle glycogen and liver glycogen are reduced in the physiological metabolism, with heart rate increased, accompanying with changes in immune function and sympathetic nervous (endocrine) activity and emotional anxiety;

Stage IV: Based on Stage III, it's difficult to make efforts or make fewer efforts, glycolytic potential is reduced, the risk of diseases and infections is increased, stimulus concentrations change, and mood and sleep status become worse.

If the exercise performance decreases for several weeks or months, it will be considered as overtraining syndrome, which results from many reasons such as unreasonable train arrangement, monotonous training methods, boring and tasteless life, living rules broken, unreasonable diet and nutrition under the poor physical conditions of athletes, and various psychological factors (Jatupaiboon *et al.*, 2013).

Research objective

When athletes are engaged in sports activities, which are based on the stretching of muscles, but the muscle movement is controlled and regulated by the central nervous system, and at the same time, the physiological action of the central nervous system will reflect on the EEG signals. Therefore, this study focuses on the EEG of athletes with overtraining syndrome.

Research methods

The differences and similarities of EEG of 100 patients with overtraining syndrome are recorded and compared with each other, with the data of 100 healthy athletes as control. In each of the patients studied, there is a decrease in sustained motor capacity, with different degrees and signs as shown in Figure 2:

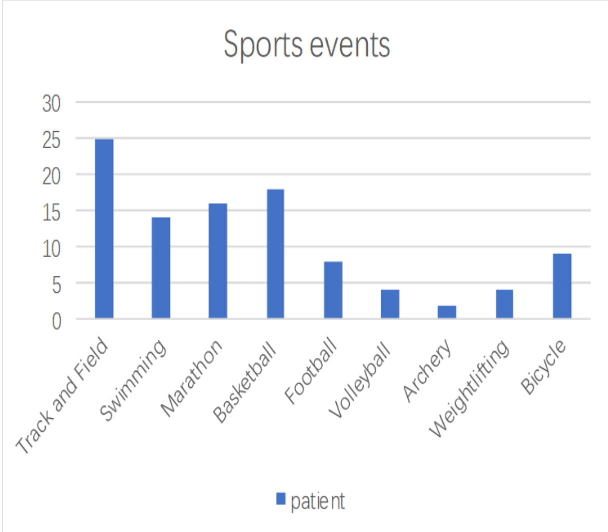

Figure 2. The event of exercise programs in patients with overtraining syndrome

Symptom and sign of Athlete with Over-training Syndrome

In this case, the patients are aged 12-32 years old, with an average age of 23.5 years old and an average sport age of 6.3 years, including 59 male athletes and 41 female athlete. When tracing and measuring, the patients take a seat and keep the eyes awake.

In 100 patients with overtraining syndrome, the symptoms in the nervous system are more obvious. According to the number of corresponding symptoms, there are such psychological symptoms as fatigue, poor sleep condition, headache, dizziness and boredom training in turn. In addition, the patients have decreased immunity, memory decline, menstrual disorder, anorexia and other symptoms (Lotte *et al.*, 2007).

The EEG Characteristics of Athlete with Over-training Syndrome

The α-index is low and the fluctuation range of α-wave rate is increased

The direct range of α wave is 20~78%, and the mean value is 52.1%. It's divided into three groups as below 50%, 51%~69% and above 79% respectively. Compared with the normal level, the α-index of the overtraining group is obviously decreased. (Difference judgment: t=difference of two numbers/standard error, t<2.5 indicating no significant difference, 2.5<t<3 indicating difference, and t>3 indicating significant difference). See Figure 3 and 4 for details:

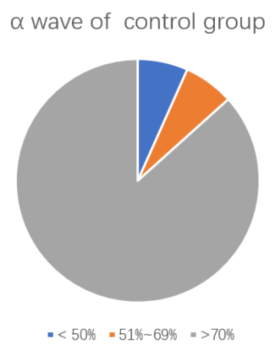

Figure 3. Comparison of the distribution of α wave index in Control Group

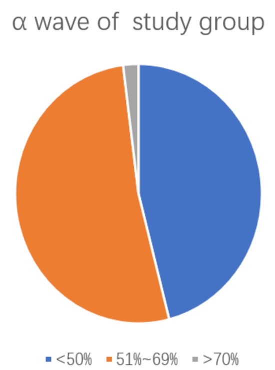

Figure 4. Comparison of the distribution of α wave index in Study Group

β-wave amplitude of exorbitant occipital

In patients with overtraining syndrome, there is a tendency to the β-wave increase in the occipital region and too high β-wave is regarded as abnormal in medicine.

3θ-wave in an explosive and paroxysmal form

The most frequent occurrence of slow wave rate is θ-wave of low frequency, and it mostly appears in an explosive and paroxysmal form,

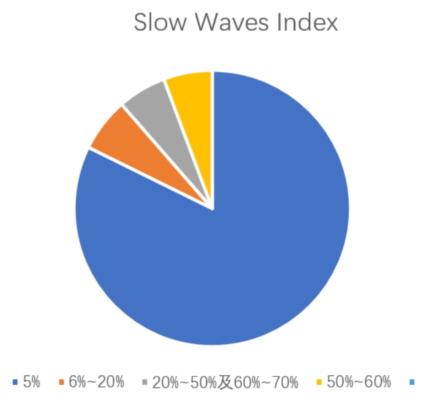

Figure 5. Slow Waves Index

with certain diagnostic value. Slow waves are observed in all cases of the overtraining syndrome group.See Figure 5 for details:

In the control group, for no more than 20% patients, the amplitude of slow wave in the overtraining syndrome group is higher than that in the control group. The amplitude of slow wave of 36.2% subjects is higher than 75~150μV, and the highest is over 270μV (Ramírez-Amaya *et al.*, 1999).

Hyperventilation Induced Experimental Characteristics of Athlete with Over-training Syndrome

The amplitude of α-wave increases, and the range of θ-wave appears more widely

(1) The part appearing slow wave after hyperventilation is more extensive and that in or after hyperventilation is more than that in quiet. In terms of the occurrence form of slow wave in hyperventilation, compared to that in quiet, single scattered parts reduce in or after hyperventilation and some are presented in a diffuse and paroxysmal form.

(2) The amplitude of α-wave increases in both groups after 3min from the start of hyperventilation test (Adey and Walter, 2013). However, there is a significant difference in the amplitude of the increase, up by 11.2μV in the control group. In the overtraining syndrome group, the amplitude of patients after hyperventilation is 4.22μV more than that before ventilation.

(3) There is a significant increase in slow wave index of 83 cases in or after hyperventilation. After hyperventilation, there is persistent high-amplitude slow wave (about 60% of the patients had slow wave index of greater than 11% after 30 s since the stop of hyperventilation). When the hyperventilation stops for 30 seconds, a large number of slow waves or high-amplitude slow waves still appear, which has clinical pathological significance. The reason is that hyperventilation leads to the lower partial pressure of carbon dioxide, and the decrease of of 0.1333 kPa in the partial pressure of carbon dioxide every from the normal value can reduce the cerebral blood supply by 1.5mL. May cause the brain tissue to be short-term hypoxic intolerance, resulting in a large number of slow waves. This suggests that brain cells of patients with overtraining can cause cerebral vasoconstriction in the case of hypocapnia, and in the case of reduced cerebral blood flow, it may

result in the brain tissue to be intolerant to transient hypoxia, thus causing the appearance of a large number of slow waves.

Characteristic description of slow waves

The patterns of hyperventilation are compared among before, after and during the excitation experiment, and EEG is recorded continuously during hyperventilation. The effect of hyperventilation on EEG is also marked by slow wave, so only the change of slow wave is analyzed here.

(1) Slow waves are more widespread and are more likely to occur when or after hyperventilation than when they are quiet. As an example, after t-test, there is a significant difference in the increase of slow wave after hyperventilation compared with quiet, and the increase is not significant enough after hyperventilation compared with quiet (Sovierzoski *et al.*, 2008).

(2) The appearance form of slow wave In or after hyperventilation, there is a significant decrease in the single scattered form in the originally quiet state, and some turn into a diffuse and paroxysmal form.

(3) Slow wave index: In 65 cases, the slow wave index is significantly higher than that in quiet, and there is only 37.4% of cases when the slow wave index is over 10% in quiet while the slow wave index is 63.7% and 51% respectively in or after hyperventilation.

A large number of slow waves or high-amplitude slow waves induced by the hyperventilation induction test still appear after 30 seconds since the experiment stops, which is clinically considered to be of pathological significance (Bird *et al.*, 2008). It can be seen from the graph that the marginal EEG has a certain degree of abnormal pattern. In this study, there are 30 cases with such diagnosis and above, that's, 60 intestines are associated with abnormal EEG in the overtraining syndrome group. A total of 32 graphs on following up and observation is carried out to samples. With the increase of time, the amount of exercise and therapeutic measures are adjusted. The results are as follows: 8 patients (more than 3 months) recover from the marginal state to the normal range. Each decrease of 1 mm Hg in normal value may reduce cerebral blood flow by 1.5 ml. This suggests that the brain cells of overtrained athletes make the cerebral vessels contract in case of hypocarbia. Under the condition of reduced cerebral blood flow, the brain tissue cannot easily tolerate the transient hypoxia and may induce a large number of slow waves, while under the condition of severe hypoxia, the athletes have much fewer slow waves than those who exercise physically. This also means that athletes with more slow waves must be less resistant to hypoxia. EEG in this study is within the normal range before hyperventilation stimulation, and 15 cases are diagnosed as marginal EEG and above after hyperventilation stimulation (Turnip and Hong, 2012). It can be seen that the hyperventilation stimulation test, like the step test in the diagnosis of cardiovascular diseases, can increase the positive rate of diagnosis, which is about doubled in this study. According to the classification of EEG diagnosis in 100 cases, there are (a) 0 case with normal EEG, (b) 40 cases with normal range of EEG, (c) 44 cases with marginal EEG, (d) 6 cases with mild abnormal EEG and (e) 5 cases with moderate abnormal EEG. As shown in figure 6.

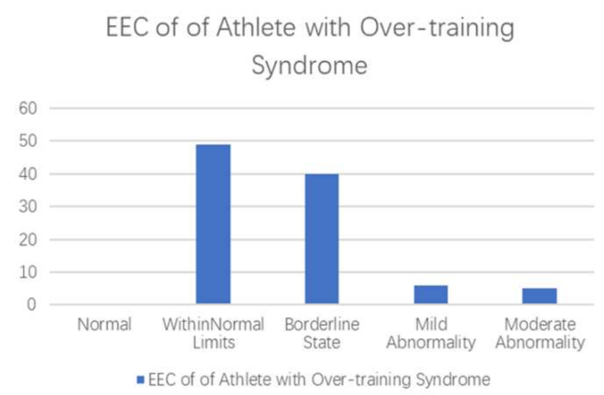

Figure 6. EEC of of Athlete with Over-training Syndrome

Characteristics of Athlete with Over-training Syndrome after Exercise

The fluctuation range of α-wave rate decreases after patients with overtraining syndrome have load.

The amplitude of α-wave is significantly increased in the control group after 15s' high leg lifting exercise, and there is no significant change or a decrease in the overtraining syndrome group. In recent years, the computer technologies have been applied to compare and analyze the EEG power spectrum of athletes in over-training state and normal state, and the variation law of EEG can be observed in frequency domain. By the power spectrum, the EEG power spectrum of 21 athletes among 22 athletes during training is abnormal. In the frequency domain, the relative energy of the central region θ frequency band increases in quiet, the relative energy of the α frequency band decreases, and before and after the hyperventilation experiment, the difference of α peak frequency between central region and occipital region is increased (Beserve *et al.*, 2007). In this way, the abnormal rate of over-training EEG by comparing and measuring from EEG frequency domain is 9% higher than that of routine EEG analysis.

Conclusions

EEG is applied in sports scientific research. In a word, it is valuable to apply EEG knowledge to select materials and guide sports training. EEG is objective, quantifiable and reproducible. However, its waveform is complicate, and especially for the low amplitude, abnormal diffuse, and scattered slow wave, it is difficult to judge and analyze. Although it has been widely use in clinic, it has been still visually analyzed by clinicians so far, and such analysis result may be largely influenced by subjective factors, so that EEG results lack the quantitative index in different periods and among different individuals, which makes the diagnostic value limited. In recent year, with the development of electronic industry, the spatial technology of EEG map has been formed, and it is an imaging technology for analyzing and displaying spontaneous EEG and evoking EEG activity information in two-dimensional form. EEG map has the advantages of strong visuality, quantitative analysis and sensitivity. Although it is superior to EEG, it also has its disadvantages, so the two should be combined with each other for complementary instead of replacement. The application of EEG in sports research is very limited, and the application of EEG map in sports research has not been seen in China. It is urgent for sports workers to make more efforts to apply the relevant knowledge of EEG map in sports practice as soon as possible.

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