CHAOTIC CHARACTER OF SPRINTER'S MYOELECTRIC SIGNAL

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There are different myoelectric reactions during muscle's motion when athletes are at different training stage. This study analyzed the myoelectric signal at different training stage of athletes according to chaotic theory and found that there were differences in the spectrum character of myoelectric signal and embedding dimension at different training stage of athletes. The results show that the myoelectric signal spectrum at relaxed status of the muscles mainly presents random noisy spectrum character, but the myoelectric signal spectrum at concentric contraction of the muscles presents divided modality spectrum character. The embedding dimension of myoelectric signal is obviously less at contracted status than at relaxed status. The relative value of embedding dimension of myoelectric signal is far larger during the preparation before tournament than during the transition stage.

KEY WORDS: myoelectric signal, chaotic character, embedding dimension.

INTRODUCTION: Human movement capacity can be exhibited on different levels and is much less in fatigue or illness than normal or sport status. The muscles are the active part of human body. The nerve control capacity, the metabolism and biomechanics characters of the muscles are still fields to be explored deeply. Electromygram is widely used in athletic sports, successful examples of which are in the study of the different status of the muscles, the harmony degree among the muscles, and contraction type and strength, and in the evaluation of muscle's fatigue degree, injury, and making etc. Different training degree athletes have different myoelectric reaction in working. It has been proved by a lot of lab research work. Synchronised discharge is often seen in well-trained athletes when the muscles contract explosively and vigorously. Nevertheless, synchronised discharge is often seen in the person who never participates in sports. Myoelectricity analysis in sport physiology study has two main aspects, amplitude and frequency. Amplitude reflects the level of electromygram parameters.

The aim of this study is to explore a new method for analysing electromygram, and describe the craftsmanship status of an athlete with new parameters. That is to say, through extracting myoelectric signal essential characters (Myoelectric signal as a time series), we try to find quantitative description parameters of electromygram. Through testing the myoelectric signal on the surface of the movement muscle's group of athletes, we introduce the methods in fractal theory and chaotic theory into the analysis of myoelectric signal, this study analysed myoelectric signal quantitatively, in order to find a new method to analyse myoelectric signal, to describe the training level and physical condition basing on myoelectric signal quantitatively, to establish training level and physical status record for movement quantitative evaluation of coach and athletes, and to provide theoretical base for coaching movement training scientifically.

METHODS: This study applied Biodex 900 - 220 type tache moment isovel measuring system (US) to measure the extending knee moment of the right knee extensor group of subjects at different rotary speed and applied SIERRA E615466 type electromygram evoked-potential meter (US) to measure the myoelectric signal on the surface of three ends of the right quadriceps femoris, at the same time, to record the extending knee moment and surface electromygram of subjects. The subjects are all male sprinters.

Chaotic Character of Myoelectricity: We will discuss the degree of freedom corresponding to myoelectric signal of kinetic system, using one of the effective methods of researching chaotic character in the latest physics, phase space reconstruction method. The phase space is a physical concept. For a system with single degree of freedom, the according phase space (plane) is the displacement-velocity plane. When a system makes cycle movement, the moving orbit of particle is an ellipse in the phase plane. The complexity of a chaotic dynamics system can be clearly depicted by the orbit in some lower-dimensional phase plane of the phase space. But how many degrees of freedom there are in the system can not be found out from the lower-dimensional phase plane. Phase space reconstruction method is a new method, developed in the study of complicated/chaotic dynamics system in physics. It can be used to evaluate the effective degree of freedom of the considering system, and to reconstruct signals through an effective lower-dimensional dynamics system.

Principle: Phase space reconstruction method (PSRM in short) usually deals with one-dimensional signal, which is the projection of higher-dimensional phase space "orbits" of a system onto a one-dimension observing axis. The goal of the PSRM is to estimate the effective dimension of a system under considering and then approximate/reconstruct the system by an effective lower-dimensional dynamics system. A crucial step in the PSRM is to calculate the least phase space dimension of the system. There exits several methods to do this work (Takens, F., 1981; Liebert. W. & Schuster H. G., 1989). We will describe below in detail the false near neighbour method that we use in this study.

First, for a given signal sequence $x(n)=x(t_0+n\Delta t)$, n=1, 2,..., N, we reconstruct m dimension phase space vectors by time-delay coordinates,

$$X_n=\{x(n),x(n+\tau),...x(n+(m-1)\tau)\}. \quad (3\text{-}1)$$

The time-delay parameter τ is determined by the first minimum of the mutual information function $Im(\tau)$ defined as follows,

$$\mathrm{Im}(\tau)=mH_0-H_m(\tau) \quad (3\text{-}2)$$

$$H_m=\frac{1}{M}\sum_{i=1}^{M}\log P_\epsilon(X_n) \quad , \quad M\le N \quad (3\text{-}3)$$

$$P_\epsilon(X_n)=\frac{1}{N}\sum_{j=1}^{N}\Theta(\epsilon-|X_n-X_j|) \quad (3\text{-}4)$$

where, $\Theta(x)=\begin{cases}1, x\ge 0\\ 0, x<0\end{cases}$ denotes the step function. $P_\epsilon(X_n)$ is the probability of the events, which a m-dimensional vector X_j falls into the m-dimensional ball with X_n as the centre and ϵ as the radius.

Next, we use the false near neighbour method to determine effective embedding dimension of the phase space. The false near neighbour method is a powerful tool to find the effective embedding dimension of a dynamics system. The basic idea is described below. Near neighbour rate is the ratio of the number of false near neighbour points to the number of total near neighbour points. With the increasing of the dimensions, the number of false near neighbour point decreases and near neighbour rate decreases. When near neighbour rate becomes constant, the corresponding dimension is the least embedding dimension m_d. For more details on the false near neighbour method, we refer the reader to references.

RESULTS AND DISCUSSION: In this study, we calculate and analysis the embedding dimension of the myoelectric signal of international master athletes at general preparation period and at transition period by using the false near neighbor method. The Table 1 shows that the embedding dimension of myoelectric signal is about 4-8 in concentric contraction status of the muscles, while the embedding dimension of myoelectric signal increases remarkably to 12-19 in relaxed status of muscles. This quantitative relationship seems related to synchronised electric discharge. If we consider the number of embedding dimensions as the number of effective motor units of the muscles involved, it is clear that there exist random electric discharge of the motor unit of a lot of muscles on the surface in relaxed status. By contrast, the motor units of the muscles show synchronised discharge in concentric contraction of the muscles; there shows high correlation among the muscles and a low embedding dimension. The results are consistent with the conclusion of the fractal dimension analysis of myoelectric signals in different training status made by Qu Feng.

Table 1 Embedding dimensions of myoelectric signals of different level athletes.

Athlete Level	Embedding dimension in contracted status of muscles ($\bar{t}$)	Embedding dimension in relaxed status of muscles ($\bar{l}$)	Variance l-t	(l-t)/t
before tournament	5	16	11	2.2
after tournament	7	14	7	1

The muscle fibre motor unit of the muscle of master athletes has a higher capacity. The co-operation among motor units and the ordered contraction and relaxation capacity are excellent. The fractal dimension and embedding dimension analysis of myoelectric signal achieved in this study provides a useful way to describe quantitatively the capacity level of athlete in concentric contraction and relaxed status. The embedding dimension of myoelectric signal at different stage of the training of athletes is different as table showed. The analytic results are as follows:

The embedding dimension of myoelectric signal at the contracted status: The embedding dimension of myoelectric signal of the athletes at the stationary training stage is smaller than that at the fallow stage. The embedding dimension of myoelectric signal in the relaxed status of the muscles: The embedding dimension of myoelectric signal of the athletes at the stationary training stage is larger than that at the fallow stage. This can be seen from the relative value, (l-t)/t in Table 1. The relative value of embedding dimension in a stationary stage is remarkably larger than that in a fallow stage. The result is consistent with the above said result of fractal dimension analysis of the myoelectric signal: with the increasing of the performance capacity of athletes, the fractal dimension of myoelectric signal of the muscle decreases; the fractal dimension of myoelectric signal of the muscle arrives at the largest when the muscles are in completely relaxed status.

CONCLUSION: The embedding dimension of myoelectric signal in contracted status of muscles: The embedding dimension of the myoelectric signal in the relative constant status of athletes is smaller than that in fallow stage. The embedding dimension of myoelectric signal in relaxed status of the muscles: The embedding dimension of myoelectric signal in the relative constant status of athletes is larger than that in fallow stage.The relative value of embedding dimension in the before-tournament preparation period, high competition capacity status, is remarkably larger than that in after-tournament transition period, low competition status.

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