APPLICATION OF AN ARMA-MODEL AS A METHOD OF TIME-VARIANT SPECTRAL ANALYSIS TO SURFACE EMG-SIGNALS IN SWIM BENCH EXERCISES

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The purpose of this study is the determination of spectral parameters of surface EMG signals during a swim specific exercise by means of an ARMA model. This method is suitable for nonstationary signals such as EMG, MEG and EMG. Nine female top elite swimmers participated in this research. During a two minute swim bench exercise the momentary median frequency decreases. Changes of the EMG power for the different wave bands could be found. By means of this analysis information about fatigue and changes in the intramuscular coordination are possible.

KEY WORDS: surface EMG, swimming, frequency analysis.

INTRODUCTION: The surface electromyography is a well- known and often used method to characterize the exercises and to optimise the sports training. Special questions about fatigue and activation of muscle require time-dependent analyses of frequencies. To solve this problem several methods are available. For instance, the Fast Fourier transform is often used. However, this technique requires stationary signals. By applying a sliding window, the estimation of a high spectral density with a high time resolution is not possible. Another method is the wavelet-analysis (Tscharner, 2000). In result of this wavelet transform, intensity plots are generated for chosen wave bands. This procedure allows only a visual impression of the frequency-time relationship. Schack et al. (1995) developed an adaptive procedure of fitting time-dependent ARMA models to nonstationary signals.
The aim of this paper is the using of this ARMA model to calculate time-dependent spectral parameters of surface EMG signals under the condition of a swim specific exercise test.

METHODS: The swim specific movements of nine female elite swimmers on an isokinetic swim bench were analysed over a training period of nine month in 2002/2003. Surface EMG-signals of the m. triceps brachii (caput laterale and caput longum) and m. latissimus dorsi and mechanical power were acquired over a 120-second period of a maximal voluntary endurance-load-swim-bench-exercise. Time-dependent spectra, median frequency and time dependent power for single wave bands were analysed by using the ARMA model by Schack et al. (1995). Fig. 1 shows the general determination of the momentary median frequency from the spectral density.

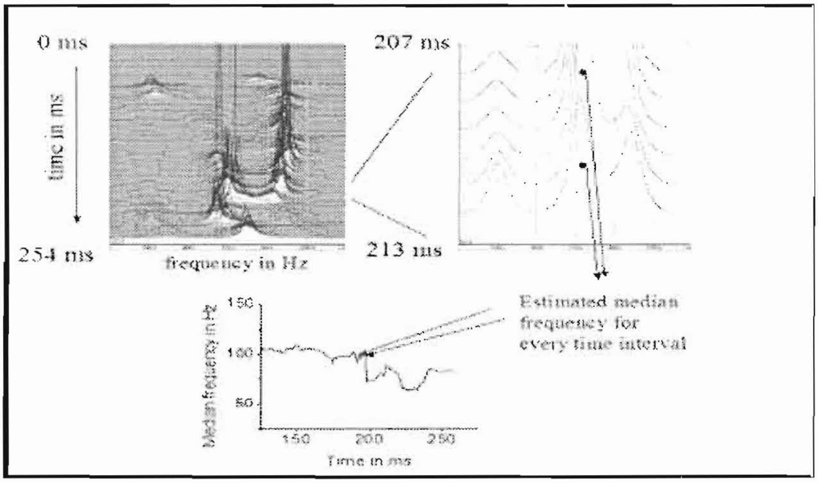

Figure 1: Method of estimation momentary median frequency from the time-dependent spectra, top left: time-dependent spectra, top right: blow up of the spectra, down: momentary median frequency.

RESULTS AND DISCUSSION: At first we computed the time-dependent spectra for single movements cycles at the beginning and at the end of the 120 s exercise. Fig. 2 shows an example for one swimmer.

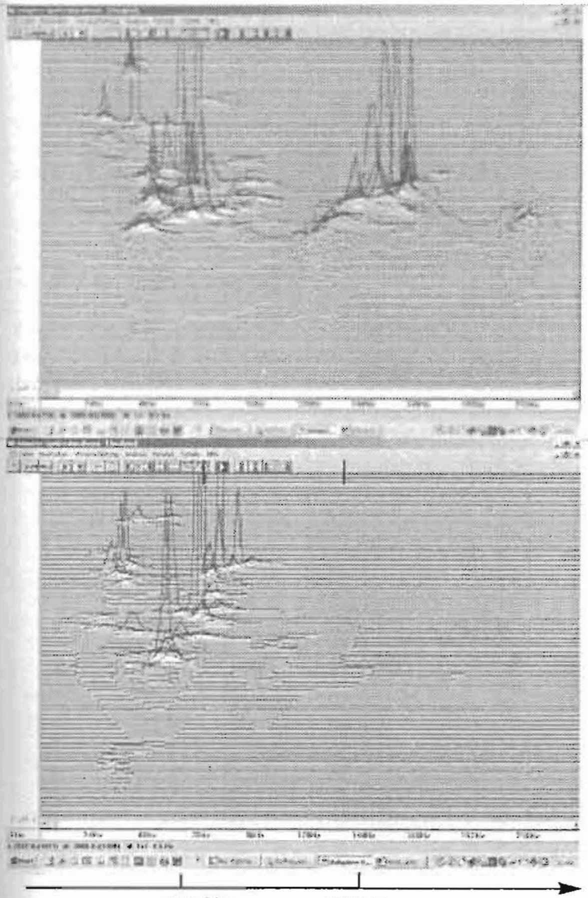

Figure 2: Examples for time-dependent spectra of the m.tric.lat. - a cycle at the beginning (top) and a cycle at the end (down) of the exercise.

We found similar spectra for the other cycles and the other swimmers. Generally, it can be concluded that at the end of the exercise the higher wave bands vanished. Therefore, the median frequencies decreased during the exercise. In Fig. 3 for the swimmer III the mean median frequencies for 4 time intervals (0-30s, 30-60s, 60-90s and 90-120s) are drawn. We have to note that these characteristics are inter-individually different.

From this diagram, it is evident that the time curve of the median frequency at the end of the test is lower than the other curves. This effect is typical for progressive fatigue.

The decreasing of the mean median frequency during the exercise was observable for all three muscles, but the differences varied with the swimmers' performance level (Fig. 4). We can note that the swimmer III was world champion at this time. She shows the lowest decrease of the frequency though her mechanical power decreases clearly (compare Fig. 3 with Fig. 5).

From these results we can assume that we should find changes in the estimated power of the EMG signals dependent on the wave bands. Fig. 6 shows the time course of the estimated EMG power for several wave bands. To quantify these curves we computed the integrals of the EMG powers. Fig. 7 shows these integrals for five cycles at the beginning and for five cycles at the end of the exercise for swimmer III. It can be seen that at the end of the exercise the integral of the EMG power of the higher wave bands is lower than at the beginning. Specially, the mean percentage of the integrated EMG power in the 100-150 Hz wave band is smaller for the last cycles than for the first cycles. But, for the first cycles we found up to 10 % of the integrated EMG power in the 150-200 Hz wave band and for the last cycles this value was not higher than 4 %.

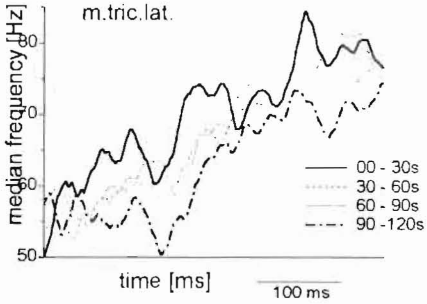

Figure 3: Mean median frequencies of the m.tric.lat. for 4 time intervals during the 120-s exercise, swimmer III.

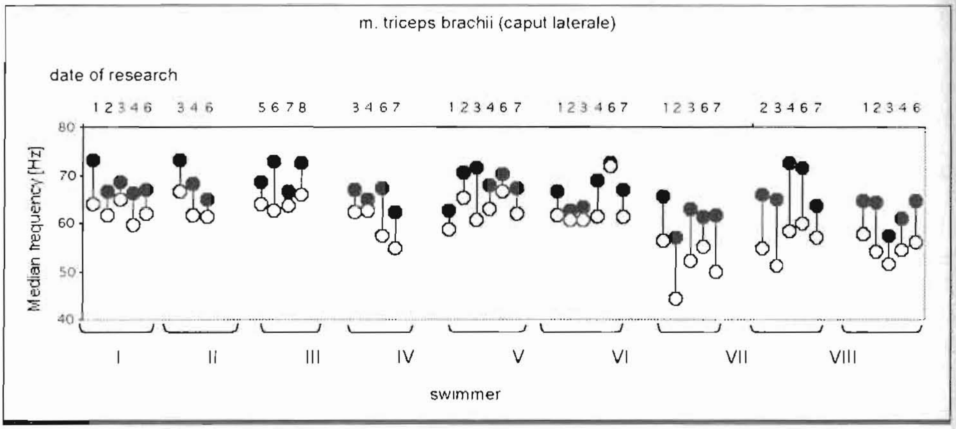

Figure 4: Mean median frequency for all swimmers and for each date of research.
● - mean value for the first 20 cycles,
○ - mean value for the last 20 cycles.

CONCLUSION: By application of the ARMA model by Schack et al. (1995) to surface EMG signals information about the time-dependent behaviour of the frequencies and the signal power can be given. We found a decrease of the median frequency during the swim specific exercise. A plausible explanation is the progressive fatigue. In difference to other methods accurate determinations of the time when the median frequency is decreasing is possible. Additionally, the EMG power for the single wave bands can be estimated. Therefore, we can obtain quantities about the neuromuscular changes during an exercise.

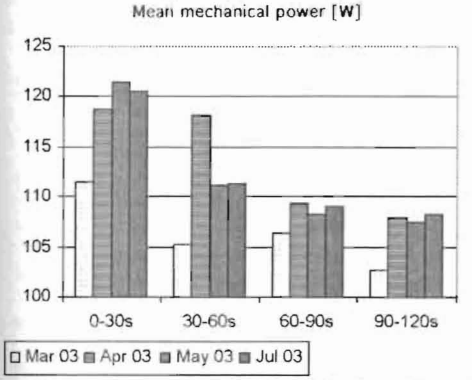

Figure 5: Mean mechanical power for the 4 time intervals of all dates of research (swimmer III).

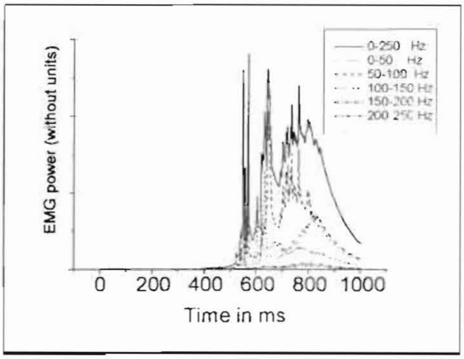

Figure 6: Estimated EMG power for several wave bands, swimmer III, m.tric.lat. cycle of the beginning of the exercise.

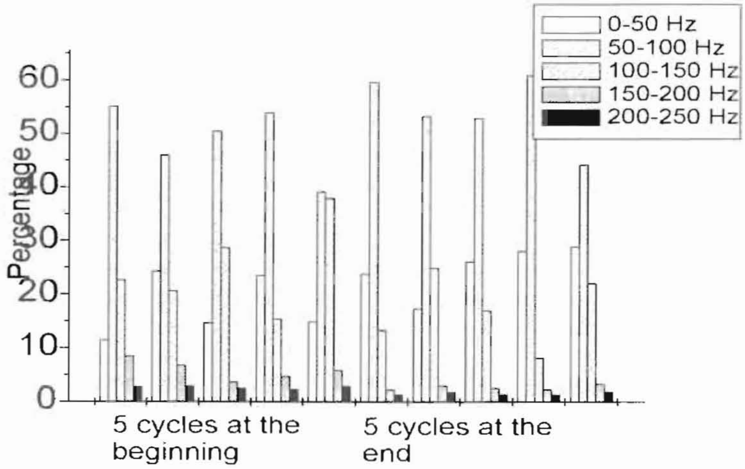

Figure 7: Percentage of the integral of the estimated wave band powers in relation to the total power (0-250 Hz), swimmer III.

REFERENCES:

Schack, B., Bareshova, E., Grieszbach, G., Witte, H. (1995) Methods of Dynamic Spectral Analysis by Self-exciting ARMA Models and their Application to Analysing Biosignals, Med. & Biol. Eng. & Com-put., 33, 492-498.

v. Tscharner, V. (2000): Intensity analysis in time-frequency space of surface myoelectric signals by wavelets of specified resolution. J. of electromyography and Kinesiology, 10(6) 433-445.

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