Spectral analysis in cyclic changes of human sleep evaluation

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Abstract. In this study cyclic changes of human sleep structure were examined. For whole-night polysomnograms of 35 healthy volunteers of both sexes, manual hypnograms were created and divided into NREM-REM cycles. EEG signals from C3-A2 derivation were analysed by computer using a Fast Fourier Transform (FFT). For consecutive NREM-REM cycles of individual sleep stages, EEG power density contents for delta, theta, alpha, sigma and beta waves were analysed. For consecutive sleep cycles, a clear decrease in NREM sleep duration, especially slow wave sleep duration, was obtained. In addition, a decrease in power density of delta waves was observed. For consecutive sleep cycles, increases in REM sleep duration and in power density of theta and alpha waves were obtained. In consecutive sleep cycles, high amplitude delta slow waves are replaced by higher frequency and lower amplitude waves. Thus stages of NREM sleep are replaced by stages of REM.

In whole-night sleep records cyclic changes of polysomnographic structure are observed. In this study an attempt to analyse these changes was made using manual analysis according to standard criteria (Rechtschaffen and Kales 1968) and by computer analysis, using EEG power spectral analysis (Pracka et al. 1991, Pracki et al. 1995).

Sleep records of healthy volunteers of both sexes with day-work activity, were studied in the sleep laboratory, following an adaptation night, using non-invasive technique. Records of all-night poly-somnograms with a minimum duration of 6 h were obtained for 35 subjects (23 female, 12 male) aged 19-26 years (mean 23.09, SD 2.08).

For the purpose of data collection and analysis the SOMNOSCAN computer system for human polysomnogram analysis (Pracki et al. 1990), was employed. It consists of a 16-channel polygraph connected through a fast 12-bit AD converter to an IBM-PC computer. The converter transformes polygraphic analog signals into digital signals with a sampling frequency of 102.4 Hz. Digital data are sent to the computer where they are fully analysed. These data and analysis results are recorded on a hard disc as well as displayed on-line on the monitor.

In this study, standard electrode placement was used according to the recommendations of Rechtschaffen and Kales (1968). For better alpha detection, an additional EEG derivation (C3-O1) was employed. EEG signals for two EEG channels (C3-A2, C3-O1) in the frequency band of 0.5-30 Hz, sensitivity 50.0 µV/cm, two EOG (0.5-30.0 Hz, 100.0 µV/cm) were collected from silver/silver chloride electrodes attached by collodium. In addition a spontaneous motor activity (ACT) was recorded from a wrist actograph containing a piezoelectric transducer (Pracki et al. 1992). Electromogram (EMG) and respirogram (RESP) were also recorded.

Using traditional visual analysis hypnograms were created for all polysomnograms, then each hypnogram was divided into NREM-REM cycles (Rechtschaffen and Kales 1968). Subsequently they were supplied to the computer. Mean power densities were counted for all polysomnograms and for all cycles.

For the first EEG derivation (C3-A2) the power densities were computed. Using a Fast Fourier Transformation (FFT) routine data from the EEG derivation were at first normalized and smoothed using a Hann's function, next they were analysed and averaged by Cooley-Tukey's method (Otnes and Enochson 1978). For each 30 s epoch of the polysomnogram, divided on six 5 s data blocks, power densities were computed, then smoothed and averaged. One hundred twenty four power density intervals in frequency band of 0.4-25.0 Hz were obtained.

For 4 consecutive NREM-REM cycles of all 35 polysomnograms, the duration of sleep stages and percentage power density contents for delta (0.4-4.0 Hz), theta (4.0-8.0 Hz), alpha (8.0-12.0 Hz), sigma (12.0-14.8 Hz) and beta (14.8-25.0 Hz) waves were counted. The results obtained were averaged for each 30 s epoch of all 32603 epochs studied.

For the comparison of two mean values, a parametric test of significance was employed. The model for a population of any statistical distribution and of finite variance, which are unknown was used, based on a normal distribution $N(0,1)$ (Greń 1975). This model of a statistical test requires two large samples, each consisting of at least several dozen elements. This condition is fulfilled for all NREM-REM cycles.

The obtained power density contents for particular EEG waves of C3-A2 derivation in consecutive NREM-REM cycles are presented in Fig. 1. Durations of NREM and REM sleep for consecutive sleep cycles are presented in Fig. 2A and durations of S1, S2, S3, S4 were presented in the Fig. 2B for consecutive NREM-REM cycles.

A cyclic decrease of delta waves power density contents (significant differences between all cycles $P<0.001$) and increase of power densities for theta (significant differences between all cycles $P<0.001$), alpha (significant differences between all cycles $P<0.001$), sigma and beta were observed for 4 consecutive NREM-REM cycles (Fig. 1A-D). Moreover clear decrease in slow wave sleep (S3 and S4) and an increase in REM sleep duration was observed for consecutive sleep cycles (Fig. 2).
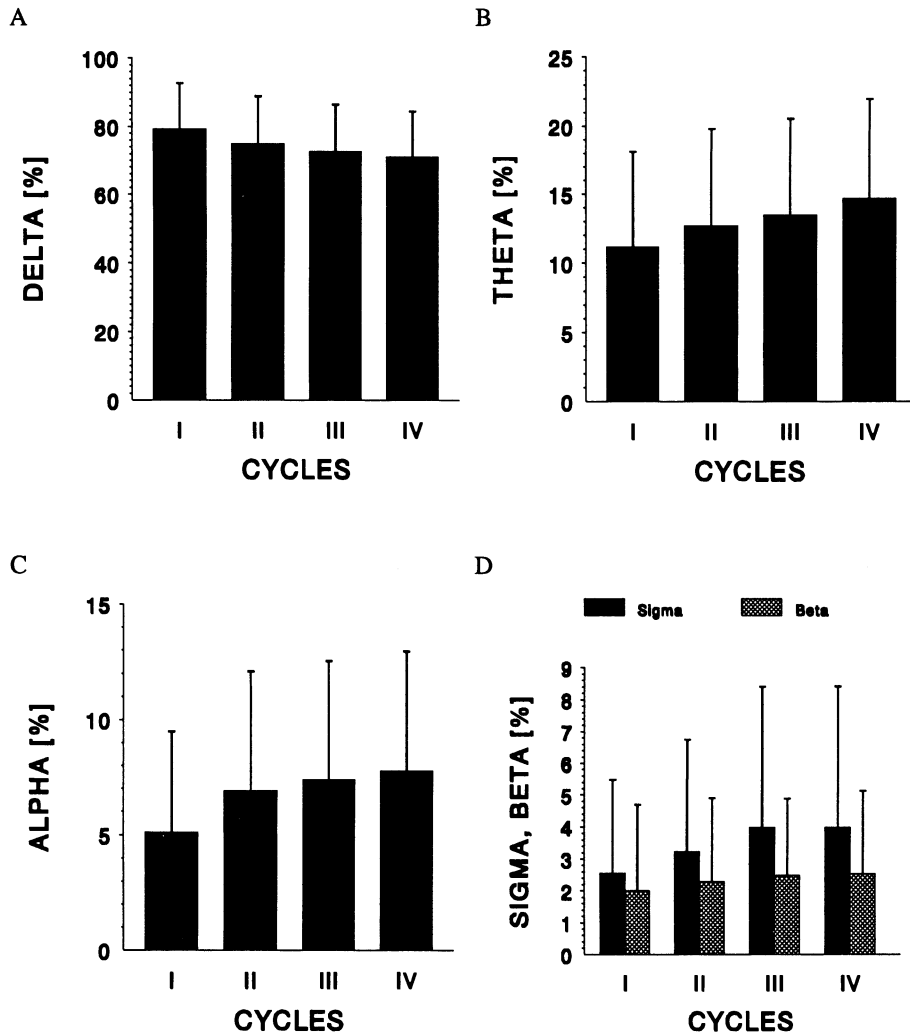
A

B

C

D

Fig. 1. EEG power density contents (mean, SD) for consecutive NREM-REM cycles. This figure illustrates: A, delta waves; B, theta waves; C, alpha waves; D, sigma and beta waves.
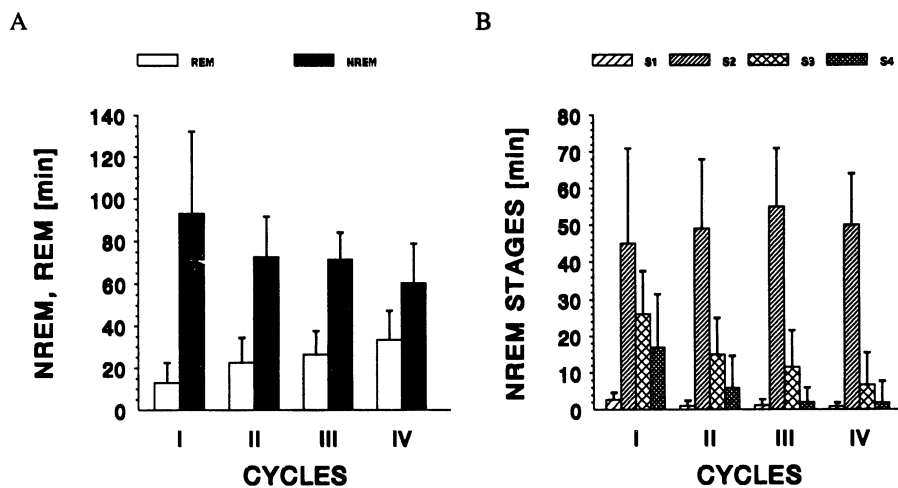
A

B

Fig. 2. Duration of NREM and REM sleep (A) and NREM sleep stages (B) for consecutive NREM-REM cycles (mean, SD).

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