SUPPORT VECTOR MACHINE CLASSIFICATION OF MUSCLE INTENSITY PATTERNS DURING PROLONGED RUNNING

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INTRODUCTION

Prolonged running results in altered muscle properties and control strategies that are expressed as changes in electromyographic (EMG) activity. Both central control and peripheral factors may change during the course of a fatiguing run and influence the frequency and amplitude of the EMG signal, respectively. In addition, EMG signals show precicely timed muscular events during a movement [1]. Our purpose was to test the hypothesis that the centrally and periferally controled features of the EMG signal change in a systematic way during a fatiguing run. If so, one should be able to discriminate between EMG measured in the non-fatigued or fatigued state. To discriminate between the early and late phases of endurance running we combined the wavelet based time-frequency analysis [2] with support vector machine classification. This study demontrates the ability of this analysis approach to quantify and classify data based on very subtle changes in the control of muscles.

METHODS

Twelve female recreational runners participated in this study. Maximum aerobic speed (MAS) was determined using an incremental treadmill running test. One to three weeks later subjects performed a 1 hour-long endurance running session at approximately 95% of their MAS. Surface electrodes were used to record EMG signals from the medial gastrocnemius (MG) muscle for 30s at 2 minute intervals throughout the run. A period of ±300 ms around heel strike was used for the analysis of the EMG.

A time frequency analysis of the EMG data was performed using von Tscharner's wavelet transform [2]. The wavelet transform resulted in EMG intensity patterns where time and frequency (center frequencies of the wavelet filters) are indicated on the abscissa and ordinate, respectively, and the grayscale represents the power of the EMG signal.

The points in each intensity pattern were placed in long vectors. These vectors were aligned side by side to form matrixes M_f and M_n containing intensity patterns measured during the non-fatigued (15-25min, N_n=185) and fatigued (45-55min, N_f=169) phases of running. These were used as reference for the classification of the vectors M_e and M_l of the early and late state of running, respectively. A support vector machine [3] with a linear kernel was used to extract a discriminant (D) between M_f and M_n. The discriminant can be displayed as an intensity pattern showing which areas contributed to the separation of the groups. The projection of the intensity patterns in M_e and M_l onto D indicated whether the intensity patterns were assigned to the fatigued or non-fatigued state. In a leave-one-out cross validation procedure the M_e and M_l of each subject were classified using the M_f and M_n of all the other subjects. The relative number of correctly assigned intensity patterns was called the recognition rate and indicated the probability of correctly assigning an unknown EMG to the fatigued or non-fatigued state. A random recognition rate would yield a 50% probability for a correct classification. A binomial test was used to test the hypothesis that the recognition rate was significantly better than random.

RESULTS AND DISCUSSION

The EMG intensity patterns recorded from the MG muscle early and late into a fatiguing run were visually not very different (figure 1). A discriminant, D, obtained using the EMG data from all subjects (fig. 2) showed that the data were separable. The EMG signals recorded during the early and late state of the run could be assigned to the fatigued and non-fatigued state with a 92.9% recognition rate (non-random with a $p < 0.05$). Shifts in frequency and timing indicate changes in muscle fibre properties and motor control strategies with fatigue.

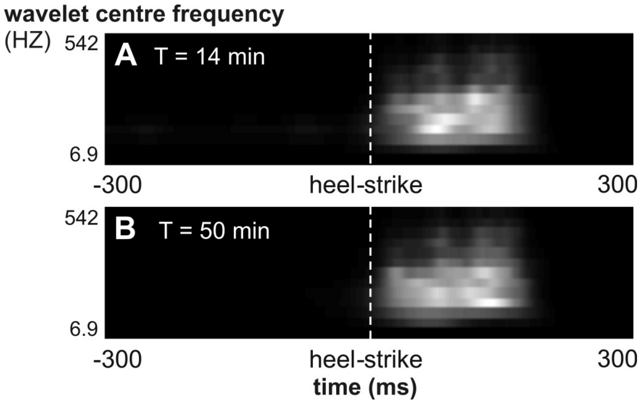

Figure 1: Intensity patterns from the medial gastrocnemius muscle at 14 minutes (A) and 50 minutes (B) into a run.

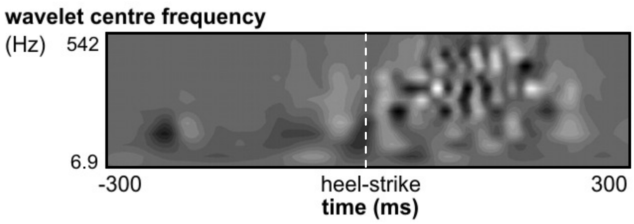

Figure 2: Intensity pattern of the discriminant, D. Increased/decreased power is shown in white/black.

CONCLUSIONS

The present study confirmed the hypothesis that the combined central and periferal controled features of the EMG change in a systematic way during a fatiguing run. The changes extracted using wavelet-based methods were highly systematic. This enabled us to classifiy, with a high reliability (92.9%), new EMG data recorded from one muscle at a single time point as belonging to a non-fatigued or fatigued state. This was achieved using a linear support vector machine to determine the discriminant.

ACKNOWLEDGEMENTS

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REFERENCES

1. V. von Tscharner, et al., *J Electromyogr Kinesiol* **16** 188-197 2006
2. V. von Tscharner, *J Electromyogr Kinesiol* **10** 433-45 2000
3. V. N. Vapnik, *Statistical Learning Theory*, Wiley-Interscience, 1998