Visualization of Changes in Muscular Activation during Barefoot and Shod Running

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Introduction

Electromyography (EMG) is a valuable tool to show changes in muscle activation caused by different conditions. The EMG signal changes with shoe condition [1], gender [2] or fatigue [5]. However, the variation between subjects is often very big and it is hard to find a general explanation how the changing condition influences muscle activation.

In pattern recognition, various statistical methods are used to overcome this problem. The purpose of this work was to apply a widely used method from pattern classification, the support-vector-machine (SVM), to the analysis of EMG signals. The intention was to differentiate between barefoot and shod running. Additionally, the method provided where in time and frequency the changes in muscle activation occurred.

Materials and methods

In a previous study 81 runners performed barefoot and shod heel-toe-running at 4 m/s [2]. EMG-signals from five muscles (gastrocnemius medialis, tibialis anterior, hamstring, rectus femoris and vastus medialis) of the right limb were recorded. Bipolar Ag/AgCl surface electrodes were used, sampled at 2400 Hz. A force plate defined the time of heel strike.

Each EMG-signal was normalized according to heel-strike by taking 300 ms before and after impact. Because of the constant running speed no time-normalization was performed. The signals were transformed to intensity patterns by a time-frequency analysis using wavelets [3]. Each intensity pattern was normalized to unit length. To create multi-muscle-patterns (MMPs), the intensity patterns of the five muscles were stacked on top of each other.

The MMPs were used to train a SVM classifier [5], using different standard kernel functions (linear, polynomial, RBF). The best kernel parameters were determined using cross-validation [6]. To evaluate the classifier, leave-one-out cross-validation was used [6]. The resulting recognition rate indicated the probability of correctly assigning an unknown EMG pattern to the correct condition. The significance of the recognition rate was verified with a binomial significance test.

When using a linear kernel the SVM can be represented by a plane in pattern space that separates barefoot from shod samples. Samples on one side of the plane are classified as barefoot, while samples on the other side are classified as shod. The normal vector W of the SVM plane points in the direction of change between the two conditions. As W is a vector in pattern space, it can be displayed as an intensity pattern. This pattern shows which areas contribute most to differentiability.

Results and discussion

The recognition rates are shown in Table 1. The linear SVM provided a high recognition rate of 89.5 %, which was significantly better than random ($p < 0.05$). Other kernels were not performing significantly better.

Table 1: Classification results barefoot vs. shod running

Classifier	correct	wrong	recognition rate
SVM (linear)	73	8	89.5 %
SVM (polyn.)	72	9	88.9 %
SVM (RBF)	71	10	87.7 %

The visualization of the difference vector W in Fig. 1 shows where an in- or decrease in muscle activity occurred when running shod or barefoot. The shoe caused a decrease in muscle activation in TA and HS directly after heel-strike. Activity was increased at +150 ms in the TA and GM and at -100 ms in the TA.

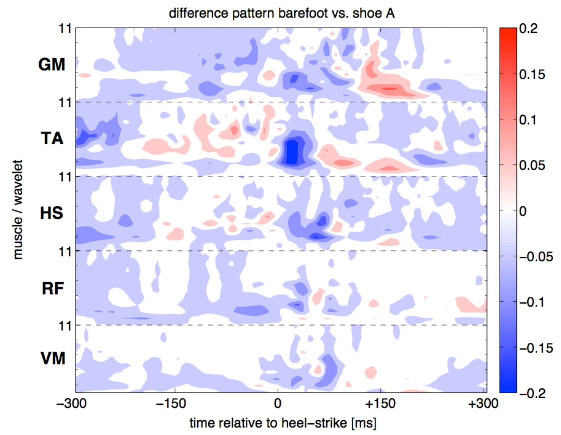

Fig. 1: Changes in muscle activation due to wearing shoes. Blue represents a decrease, red an increase in muscle activity when shod. White areas show little to no changes.

Conclusion

This work showed that the SVM predicts whether a subject is running with shoes. It also resolved muscle activation changes according to time, muscle and frequency. This is a major step towards a functional analysis and provides a great tool for future studies.

Acknowledgements

This research was supported by Adidas AG, Germany and the German Academic Exchange (DAAD).

References

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