ELSEVIER

Pathophysiology 12 (2005) 307–312

ISP PATHOPHYSIOLOGY

www.elsevier.com/locate/pathophys

# Improved evaluation of back muscle SEMG characteristics by modelling

R. Grassme [a,b,*], D. Arnold [a], Ch. Anders [a], J.P. van Dijk [c], D.F. Stegeman [c], W. Linß [d], I. Bradl [a,b], N.P. Schumann [a], H.Ch. Scholle [a]

[a] *Motor Research Group, Institute of Pathophysiology and Pathobiochemistry, University of Jena, Erfurter Strasse 35, 07743 Jena, Germany*
[b] *BG Nahrungsmittel und Gaststätten, GB Prävention, Abt. Gesundheitsschutz, Außenstelle Erfurt, Lucas Cranach-Platz 2, 99099 Erfurt, Germany*
[c] *Department of Clinical Neurophysiology (314), University Medical Centre Nijmegen, P.O. Box 9101, 6500 HB Nijmegen, The Netherlands*
[d] *Institute of Anatomy, University of Jena, 07743 Jena, Germany*

Received 9 June 2005; received in revised form 16 September 2005; accepted 16 September 2005

**Abstract**

Surface EMG (SEMG) as non-invasive method is a valuable tool in functional studies of movement co-ordination. The interpolation of the SEMG power (EMG mapping) gives information about intra- and inter-muscular co-ordination. It has been shown that SEMG maps of low back pain patients and healthy subjects differ. The only major drawback to SEMG is that volume conduction of muscle tissue, fat, and skin decreases the spatial and temporal resolution of signals. To improve the interpretation of SEMG signals, we have applied high pass filtering of cross covariance functions, which has proved to be useful in increasing the spatial resolution, to SEMG data of the back region. Experimental data demonstrate that SEMG signals from the back extensors show only rarely signs of action potential propagation. This behaviour, also described in the literature, can be explained by a model assuming short, deep muscle fibres, having bipolar end effects, with overlapping positions parallel to the fibre direction. This condition is fulfilled by the mm. multifidii et rotatores which are part of the m. erector spinae. Although the model is simplistic, the agreement between simulations and experiments is good.


*Keywords:* Back muscle; Surface EMG; Modelling; EMG-mapping; Multichannel surface EMG; Cross covariance; Action potential propagation

## 1. Introduction

Surface EMG (SEMG) is a valuable tool in the functional studies of movement co-ordination. Because this method is non-invasive and painless, it avoids an irritation of the muscles and therefore it does not influence the activation patterns. Furthermore, it is possible to apply a grid or matrix of SEMG electrodes, denoted as multi-channel SEMG. In addition to the neurological applications of multi-channel SEMG (see, e.g. [1,2]), the interpolation of the SEMG power gives information about intra- and inter-muscular co-ordination [3]. It has been shown that SEMG maps of low back pain patients and healthy subjects differ [4]. Root mean square (RMS) is typically used to roughly estimate muscle force and the activity distribution. A more detailed interpretation of SEMG is complicated due to volume conduction of muscle tissue, fat, and skin decreasing the spatial and temporal resolution of the surface EMG signal. Spatial (e.g. [5,6]) or temporal [7] filtering is able to increase the spatial resolution again.

If a row of SEMG channels is located parallel to the muscle fibre direction, the propagation of motor unit action potentials (MUAP) should cause time shifts between signals of these channels (Fig. 1), which can be estimated from the distance between channels and the muscle fibre potential conduction velocity (MFCV, about 4–6 m/s). These time shifts can be investigated by means of different methods. The action potential propagation can be observed directly (see, e.g. [8]) as it causes both time shifts in the cross covariance function (see, e.g. [9,7]) and the linear behaviour of the cross phase calculated between these channels [10]. In back muscles MUAP propagation has been shown in the m. latissimus [10]. Similar experiments for the m. erector spinae do not demonstrate such propagation of action potentials, and the cross phase has no systematic phase behaviour [11]. Also, Farina et al. [12] found experimentally that the signal is dominated by the

* Corresponding author. Tel.: +49 3641 937376; fax: +49 3641 937377.
*E-mail address:* rgra@moto.uni-jena.de (R. Grassme).

0928-4680/$ – see front matter 
doi:10.1016/j.pathophys.2005.09.011

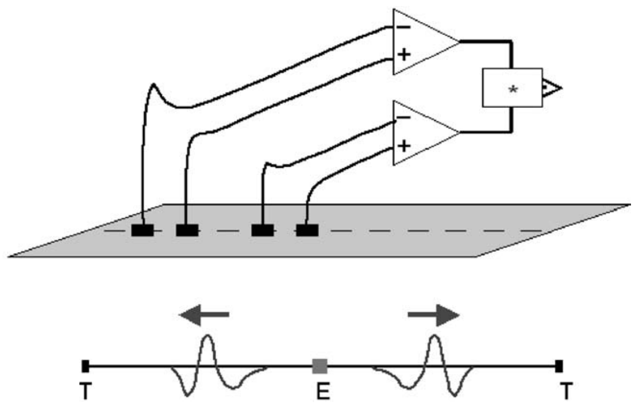


Fig. 1. Illustration of action potential propagation and correlation of bipolar SEMG channels. Muscle fibres have tendons T (causing non-propagating long range field components) and endplates E.

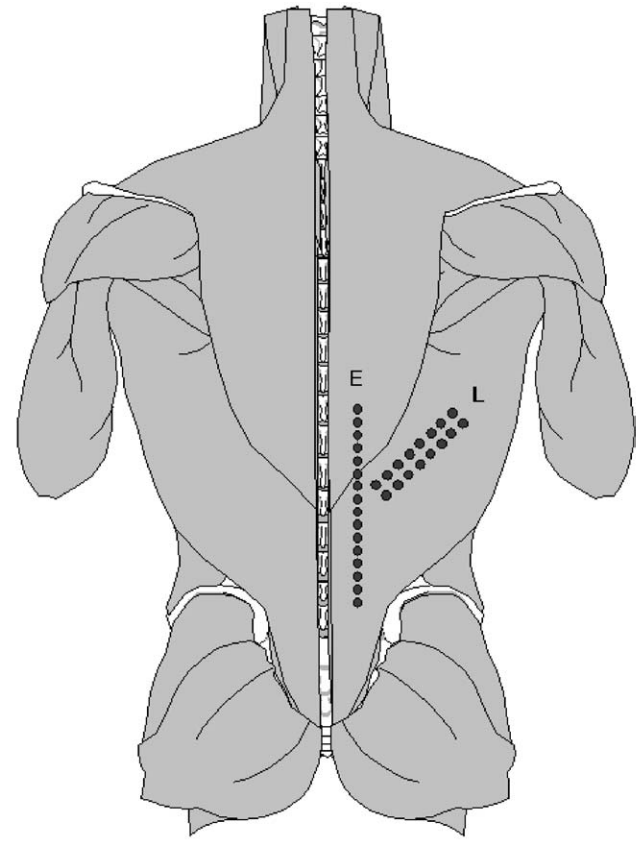


Fig. 2. Positions of surface EMG electrodes in the back region. The electrode columns are positioned for investigations of E—m. erector spinae and L—m. latissimus.

non-propagating components; propagating action potentials can be observed, but they are rare. In other words, the erector muscle seems to show a more complicated behaviour. To investigate this phenomenon further, we applied in the present study the method of high pass filtering of cross covariance functions [7] to SEMG data from the back region.

## 2. Subjects and methods

Surface EMG has been recorded from 16 subjects during a static isometric contraction of their back muscles. The location of electrodes is shown in Fig. 2. The subjects performed two exercises: one exercise was an unsupported horizontal trunk extension in prone position [13] to evoke the isolated activation of the m. erector spinae. For this investigation of the erector muscle a row of 16 monopolar surface electrodes was applied along a line parallel to the spinal column, on the belly of m. erector spinae. M. latissimus was investigated with two columns of eight electrodes which were located parallel to a line between armpit and L4 (this is approximately parallel to the fibre direction). The second exercise was a static contraction of the latissimus muscle, which was performed by holding straight arms dorsal flexed and internally rotated from prone position (the trunk was supported and therefore the extensor muscles relaxed during this exercise).

The duration of both exercises was 20 s. The SEMG signals were acquired with a sampling rate of 4000 Hz and an anti-aliasing filter with the cut-off frequencies 10–700 Hz. The inter-electrode distance was in general 1 cm. Bipolar SEMG channels were calculated by subtraction of neighbouring monopolar channels. After removing movement artefacts

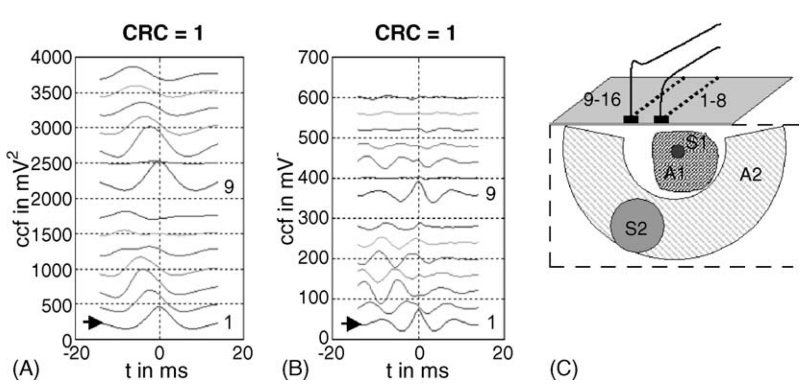


Fig. 3. Experimental SEMG cross correlation functions calculated from m. latissimus: (A) no filtering (more detailed: only high pass, $f_u = 28$ Hz to suppress movement artefacts; CRC = 1); (B) m. latissimus, high pass, $f_u = 105$ Hz (CRC = 1); (C) regions with possible EMG-sources (active fibre populations)—S1 and S2 lie anywhere in the areas A1 and A2, source S2 is stronger than S1.