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ORIGINAL ARTICLE/ARTICLE ORIGINAL

Deriving muscle fiber diameter from recorded single fiber potential

Déduire le diamètre des fibres musculaires à partir de l'enregistrement de potentiels de fibres unitaires

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KEYWORDS
Computer simulation;
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SFEMG

Summary
Objective. — The aim of the study was to estimate muscle fiber diameters through analysis of single muscle fiber potentials (SFPs) recorded in the frontalis muscle of a healthy subject.
Methods. — Our previously developed analytical and graphic method to derive fiber diameter from the analysis of the negative peak duration and the amplitude of SFP, was applied to a sample of ten SFPs recorded in vivo.
Results. — Muscle fiber diameters derived from the simulation method for the sample of frontalis muscle SFPs are consistent with anatomical data for this muscle.
Conclusions. — The results confirm the utility of proposed simulation method. Outlying data could be considered as the result of a contribution of other fibers to the potential recorded using an SFEMG electrode. Our graphic tool provides a rapid estimation of muscle fiber diameter.

MOTS CLÉS
Durée de composante négative ;
Électromyographie ;
EMG de fibre unique ;

Résumé
Objectif. — L'objectif de l'étude était d'estimer les diamètres des fibres musculaires grâce à l'analyse des potentiels de fibres musculaires unitaires (PMu) enregistrés dans le muscle frontal chez le sujet sain.
Méthodes. — La méthode analytique et graphique que nous avons développé pour déduire le diamètre des fibres à partir de l'analyse de la durée de la composante négative et de l'amplitude des PMu a été appliquée à un échantillon de dix PMu réels.

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Potentiel de fibre unitaire ; Simulation par ordinateur

Résultats. — Les diamètres de fibres musculaires déduits de la méthode de simulation pour l'échantillon de Pmu du muscle frontal sont compatibles avec les données anatomiques de ce muscle.
Discussion. — Les résultats confirment l'utilité de la méthode de simulation proposée. Les « outliers » pourraient être considérés comme résultant d'une contribution d'autres fibres au potentiel enregistré à l'aide d'une électrode de fibre unique. Notre outil graphique permet d'avoir une idée rapide du diamètre des fibres musculaires.

Introduction

Muscle fiber diameter measurements can be useful, since in some neuromuscular disorders a primary change in the motor unit involves increased variability of muscle fiber diameter [1,3,10,11]. Variability of diameter may be studied indirectly through the investigation of muscle fiber conduction velocity [10,12]. To do so, muscle fibers are stimulated directly using an intramuscular needle, and their action potentials recorded a few millimeters away. The latency of the potential is used to compute the velocity of propagation of potential along the fiber and the velocity relates in a linear fashion to muscle fiber diameter [12].

Single fiber EMG (SFEMG) is a routine procedure to study the physiological and morphological parameters of a motor unit. The diagnostic usefulness of SFEMG lies in its evaluation of fiber density as well as jitter and neuromuscular transmission [10].

Simulation studies are helpful in understanding relationships between single fiber potential (SFP) parameters and muscle fiber characteristics [13]. We previously proposed a method to determine fiber diameter and electrode-to-fiber distance from the negative peak duration (NPD) and amplitude of SFP analysis [13], through applying the model developed by Nandedkar and Stålberg [4,5]. We propose here a graphic tool that could simplify the analysis.

Rodriguez et al. [6,7] performed a similar analysis aimed at determining fiber diameter and electrode-to-fiber (radial) distance using the model of SFP dipole source developed by Dimitrova and Dimitrov [2]; they have proposed a method called the candidate pair method (CP-method) for estimation of the same quantities i.e. the radial distance and the fiber diameter. Rodriguez et al. [8] have shown that the NPD is appropriate for estimation of the intracellular action potential spike duration.

The current study sought to extend the simulation study to include analysis of in vivo data recorded using an SFEMG electrode in the frontalis muscle of a single healthy subject.

Methods

The simulation method presented by Zalewska et al. [13] concerned with the determination of fiber diameter (d) and fiber-to-electrode distance (r) from SFP. In current study the method has been modified to be more suitable for practical examinations. Instead of *NPD* being derived by reference to amplitude and fiber distance, as in our previous work, contour lines for the *d(ampl, NPD)* relationship have been drawn.

Computer simulations were performed for the fiber diameters, which ranged from $10 \leq d \leq 140\,\mu m$, with a step of $1\,\mu m$, while the fiber-to-electrode distances were in the range $25 \leq r \leq 350\,\mu m$, with a step of $5\,\mu m$. The calculated model potentials were filtered using the Butterworth filter (500 Hz—10 kHz). Since filtering affects the shape of the potential and hence its parameters, it is necessary to apply the same filter when modeling the potential as is applied in the apparatus during recording. Plots of contour lines of constant fiber diameter or fiber-to-electrode distance on the amplitude—NPD plane were constructed and are presented as graphs.

Ten SFPs recorded using Synergy EMG equipment from normal frontalis muscle (male, 55 yrs) were analysed. The parameters of SFPs are given in Table 1. We measured the amplitude of each potential and its NPD and plotted points on the graph to estimate the diameter.

Results

In Figs. 1 and 2, the graphs used to determine fiber diameter from amplitude and negative peak duration are presented for several values of fiber diameter (Fig. 1) and analogous plots for fiber-to-electrode distance are shown in Fig. 2. In Fig. 1 at constant fiber diameter, the maximum amplitude of the SFP occurs when the fiber is closest to the electrode. We have assumed this minimum distance to be $r_{min} = 25\,\mu m$. As can be seen from the graph, the curves of constant fiber diameter for fibers smaller than about $75\,\mu m$ do not extend over the whole amplitude range. This form of the graph is useful in the determination of fiber diameter, as the constant d curves are well enough separated to allow for high accuracy determinations.

As an example, data for modeled SFP with a fiber of diameter $d = 55\,\mu m$ for which the amplitude is 1.2 mV and the negative peak duration is 0.335 ms, are shown in the diagrams as a diamond. The graph in Fig. 2 shows that the fiber-to-electrode distance for the modeled fiber was $\sim 30\,\mu m$. The errors to determinations of amplitude are seen to be not very significant, since the curves are nearly flat. An accurate determination of NPD is much more important because, as the graph makes clear, an error of ± 0.02 ms in