Peripheral effects on the amplitude of monopolar and bipolar H-reflex potentials from the soleus muscle

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Summary. Variations in the amplitude of mono- and bipolarly measured H-reflex potentials can be influenced by muscle architecture and changes in muscle length. In the passive soleus muscle with the ankle joint fixed at 90°, the maximal-amplitude bipolar H-potentials were obtained along the midline of soleus at a distance of 2.0–4.0 cm below the insertion of the gastrocnemii on the Achilles tendon. In contrast, the optimal location of monopolar H-potentials was 5.0–8.0 cm below the gastrocnemii insertion. Step-wise passive shortening of soleus resulted in an increase in the amplitude of both H- and motor-unit potentials. This correspondence implicates peripheral factors, such as changes in muscle fibre diameter and inclination to the skin surface, as mechanisms mediating the changes in the amplitude of the potentials. Such effects necessitate caution in interpretation of the association between H-potential amplitude and monosynaptic reflex excitability.

Key words: H-reflex – Soleus EMG – MU potentials – Monosynaptic excitability

Introduction

The electrically induced triceps surae reflex (H-reflex) is a valuable tool to test the human monosynaptic reflex excitability under normal and pathological conditions. However, its application is limited by: a) inadequate standardization and quantification (Delwaide et al. 1980), despite the significant progress made by Hugon (1973); and b) the lack of reliable criteria for distinguishing the effects of neural (segmental and supraspinal) factors from purely peripheral ones (triceps surae structure, changes in muscle length, desynchronization of the potentials, volume conduction, etc.).

The shape and the amplitude of the bipolarly measured H-reflex compound muscle action potential (hereafter referred to as the H-potential) represent the difference in the monopolar H-potentials, measured by the two electrodes separately. This difference, which varies across the skin surface of triceps surae, depends upon the peculiarities of the extracellular potential field and muscle structure. It has been shown that both monopolarly measured H-potentials and the motor unit (MU) action potentials on which they are based provide a more complete understanding of the H-reflex and the associated monosynaptic reflex excitability; the application of monopolar measurements to the changes in muscle length produced by passive shortening or voluntary activation are especially informative (Gydikov et al. 1976a, b; Gerilovsky et al. 1977).

In order to distinguish the effects of neural factors from peripheral ones, the aim of the present work was: a) to further evaluate both mono- and bipolar measurement techniques under different conditions (passive changes in muscle length, variation of stimulus intensity, tonic voluntary activity); and b) to compare the amplitude changes of H- and MU action potentials upon changes in muscle length. Whereas the amplitude of H-potentials can be influenced by neural and peripheral factors, the amplitude of MU potentials is subject only to peripheral ones; neural factors modulate MU recruitment, firing rate and discharge pattern.

Method

Five healthy subjects were investigated. The test was performed with the subjects in a supine position. The leg under investigation was held rigidly by a special device, with the knee joint fixed at 160° and the ankle joint placed at various angles from 90° to 120°.
(see Fig. 3). The H-reflex was elicited by surface cathodal stimulation (single pulse with 1 ms duration) delivered to the tibial nerve in the popliteal fossa (cathode 1.0 cm², marked with a dotted circle in Fig. 1A). The stimulus artefact which usually accompanies monopolar measurements, was reduced using a pair of anodes 8.0 cm² each (AS₁ and AS₂ in Fig. 1A). The location of the anodes was determined empirically. They were placed symmetrically on the patella in such a manner, that on the separate application of each of them the stimulus artefact accompanying the H-signal had approximately the same shape and amplitude, but opposite polarity. The short-circuiting of the two anodes significantly reduced the artefact (Fig. 1B).

Monopolar surface H-measurements were made with a multielectrode comprising four poles, each with a small leading-off area of 1.0 mm² and interpole distance of 1.5 cm (Fig. 1C). The multielectrode was oriented along the midline of soleus. The measurements began just below the insertion of the gastrocnemii (medialis and lateralis) on the Achilles tendon in a distal direction, i.e., towards the heel. The points of recording are shown on Fig. 3, where the proximal (zero) point coincides with the distal end of the mm gastrocnemii. Monopolar measurements were made from each pole. The recordings were performed by shifting the multielectrode in a proximal to distal direction. Each new site of the multielectrode was chosen in such a way that the position of the proximal pole would coincide with the former distal pole position. At every site 16 or 32 responses were averaged. Only measurements for which the amplitude of the averaged H-potential, recorded from the proximal pole was equal to the amplitude of the H-potential, recorded from the distal pole of the previous site, were taken into consideration. Bipolar measurements were made between every two neighboring electrode poles (i.e., at 1.5 cm interpole distance) (Figs. 1C, 3).

It should be emphasized that the term "monopolar measurements" is used only for convenience since they were actually bipolar measurements in which the reference electrode was located at such a distance from the generator that the volume-conducted potentials were comparable to the noise level. For H-reflex recordings, the common reference electrode had a leading-off area of 2 cm² and was placed on the heel of the contralateral foot (for further explanation see Gydikov et al. 1976b). The stimulus artefact which usually accompanies monopolar measurements, was reduced using a pair of anodes 8.0 cm² each (AS₁ and AS₂). The location of the anodes was determined empirically. They were placed symmetrically on the patella, i.e., towards the heel. The points of recording are shown on Fig. 3, where the proximal (zero) point coincides with the distal end of the mm soleus. The measurements began just below the insertion of the gastrocnemii (medialis and lateralis) on the Achilles tendon in a distal direction, i.e., towards the heel. The points of recording are shown on Fig. 3, where the proximal (zero) point coincides with the distal end of the mm gastrocnemii. Monopolar measurements were made from each pole. The recordings were performed by shifting the multielectrode in a proximal to distal direction. Each new site of the multielectrode was chosen in such a way that the position of the proximal pole would coincide with the former distal pole position. At every site 16 or 32 responses were averaged. Only measurements for which the amplitude of the averaged H-potential, recorded from the proximal pole was equal to the amplitude of the H-potential, recorded from the distal pole of the previous site, were taken into consideration. Bipolar measurements were made between every two neighboring electrode poles (i.e., at 1.5 cm interpole distance) (Figs. 1C, 3).

A. Mono- and bipolar surface H-reflex measurements were obtained under the following conditions:

a) at different lengths of soleus (ankle joint fixed at 90°, 100°, 110°, and 120°) while the muscle was in a resting state;
b) with various stimulus intensities (from threshold to supramaximal) while the soleus muscle was relaxed and the ankle joint was fixed at 100°;
c) during moderate tonic isometric voluntary activity (10%–20% of maximum). The interference EMG pattern and the integrated EMG from the same areas on the skin surface were simultaneously measured during this condition.

B. Monopolar surface measurements of single MU potentials at different lengths of soleus (ankle joint fixed at 100°, 110° and 120°) were obtained using spike-triggered averaging techniques (Milner-Brown et al. 1973). The potentials of single MUs were selectively identified with an intramuscular, fine-wire electrode. The potentials of an identified MU were used as reference events with which to extract the MU potentials as measured along the skin. The skin-surface measurements were made with a multielectrode comprising eight poles that had an interpole distance of 0.5 cm. The multielectrode was aligned along the projection of the electrical axis of the MU onto the skin, termed the "linea maxima" (Gydikov and Kosarov 1972a; Gydikov et al. 1976a; Gydikov et al. 1981), in which the potentials displayed the greatest peak-to-peak amplitudes (Fig. 1D).

The stimulus generating equipment was a conventional Medelec USC 6 stimulating unit. The EMG data were amplified with an eight channel polyphysiograph Medelec MS 6 (bandwidth 8 Hz–8 kHz), recorded on a Schlumberger MP 3522 tape recorder and displayed on a Tektronix 5113 storage oscilloscope. The H-potentials were averaged on a Medelec averager DAV 6 (N = 16 or 32 responses). The interference EMG pattern was integrated with a Medelec 16 integrator.

Results

Changes in the amplitude of the H-potential along the midline of soleus with the muscle passive and at a fixed length

The peak-to-peak amplitudes of the monopolarly measured H-potentials were higher than those obtained bipolarly from the same area on the skin. The amplitude of both sets of potentials, i.e., monopolar and bipolar, varied along the midline of soleus over the region investigated. Both the duration of the monopolar potentials and the latency of their positive and negative maxima increased distally. With the ankle joint fixed at 90° the monopolar potentials displayed maximal amplitude values in the so called "best point" for monopolar measurements located...