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Asymmetry of magnetic motor evoked potentials recorded in calf muscles of the dominant and non-dominant lower extremity

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ABSTRACT

The aim of the study was to determine the applicability of magnetic stimulation and magnetic motor evoked potentials (MEPs) in motor asymmetry studies by obtaining quantitative and qualitative measures of efferent activity during low intensity magnetic stimulation of the dominant and non-dominant lower extremities. Magnetic stimulation of the tibial nerve in the popliteal fossa was performed in 10 healthy male right-handed and right-footed young adults. Responses were recorded from the lateral head of the gastrocnemius muscles of the right and left lower extremities. Response characteristics (duration, onset latency, amplitude) were analyzed in relation to the functional dominance of the limbs and in relation to the direction of the current in the magnetic coil by use of the Wilcoxon pair sequence test. The CCW direction of coil current was related to reduced amplitudes of recorded MEPs. Greater amplitudes of evoked potentials were recorded in the non-dominant extremity, both in the CW and CCW coil current directions, with the statistical significance of this effect ($p = 0.005$). No differences in duration of response were found in the CW current direction, while in CCW the time of the left-side response was prolonged ($p = 0.01$). In the non-dominant extremity longer onset latencies were recorded in both current directions, but only for the CW direction the side asymmetries showed a statistical significance of $p = 0.005$. In the dominant extremity the stimulation correlated with stronger paresthesias, especially using the CCW direction of coil current. The results indicate that low intensity magnetic stimulation may be useful in quantitative and qualitative research into the motor asymmetry.

In clinical applications, electro diagnosis is an extension of the neurological examination, especially in diseases of the nerves and muscles [18]. Electrophysiological assessments of muscles and nerves are now considered indispensable in the practice of neurology, physiatrics, and other related clinical disciplines. It is also used to study the neuromuscular control of movement in the treatment of motor disorders as well as in motor control studies on healthy populations [1,18,19,24,34,38]. Recording of evoked potentials (EP) is one of the most reliable methods of neuromuscular function diagnosis in humans [1,6,15,18,39]. EP needs the application of artificial stimulus to the motor system structures to initiate an impulse travelling along the motor and/or sensory nerve fibres. The motor evoked potential (MEP) techniques are useful not only for clinical applications, but also in motor control studies on healthy populations [1,12,19,36]. Experiments with MEPs are also valuable for athletic training analysis [9,10,32] and in research into the functional asymmetry of the human body [7,14,27,34].

Traditional nerve stimulation techniques use electrical stimulators for nerve activation. Surface electrode stimulation requires 50–500 V to drive currents of 5–50 mA sufficient for full nerve activation with no particular risk, unless the patient is electrically sensitive [18]. However, excitation of tissues is always connected with discomfort for a patient, and an electric shock longer than 1 ms and/or sub- or supramaximal intensity may be painful.

Magnetic stimulation is a painless and non-invasive technique for stimulating neural tissues by means of magnetic induction. Attempts to magnetically stimulate the peripheral motor system date back to 1959 in frog nerve-muscle preparation [20] and later in human nerves and brain [4]. Magnetic stimulation capable of painless excitation of the motor system has an obvious advantage over electrical stimulation in terms of patient comfort during testing [22]. A single pulsed magnetic field can elicit compound muscle action potentials (CMAPs), which confirms its utility in activating those segments of the motor system which are not easily accessible to electrical stimulation [12,18,25]. Magnetic stimulation in clinical studies is widely used in the evaluation of the motor system and

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higher brain functions in healthy and diseased states; with little emphasis on the peripheral nerves. Generally, the magnetic stimulation of peripheral nerves is reported to be technically difficult as accessible coil diameters (of about 8–10 cm or larger) may cause co-activation of nearby structures (muscles and nerves), especially at proximal sites. The reliability and utility of magnetic stimulation of peripheral nerves and the technical aspects of evoked electromyography using this technique is still under discussion. The influence of tissue non-homogeneity on peripheral nerve magnetic stimulation should be taken into consideration in any analysis of evoked potentials. Differences in nerve environment conductivity (muscles, bones, blood vessels) may be a source of errors in interpreting the electromyographic data obtained [21].

Contrary to electrical stimulation, the spatial distribution of magnetic fields cannot be effectively concentrated and focused. It is impossible to create local maxima in field intensity by the use of magnetic coils as the field strength will always be the greatest at the surface and decay monotonically at greater depths. Stimulation sites just under the skin seem to be the best for magnetic stimulation with lower intensities from a technical point of view. The utility of a magnetic impulse to activate hard-to-stimulate nerves and structures would require very strong impulses [12]. On the other hand, supramaximal stimulation in some experiments has tended to concomitantly activate nearby nerves and shows greater longitudinal dispersion than electric shock [18].

The small diameter of the coil as well as the small coil–skin distance during the magnetic stimulation of peripheral nerves permits the assessment of evoked potentials with the same reliability as any other stimulation modality [3,11,17,18,29]. However, some authors assume conventional electrical neurography to be superior magnetic neurography, and in their opinion the usefulness of magnetic stimulation on peripheral nerves needs further research [5,31].

The aim of the study was to obtain quantitative and qualitative measures of efferent activity during low intensity magnetic stimulation as a function of the current direction in the coil in the dominant and non-dominant lower extremities. Taking into consideration previous studies, we assumed that the factors that dictate the characteristics of the MEPs include the intensity of stimulus, location and orientation of the stimulating coil and intrinsic excitability of the neural elements [18]. Recently it has been shown that the amplitude of the M-wave generated by magnetic stimulation with a circular coil is dependent on the direction of current in the stimulating coil [2,38]. However, there is little information about the lateral differences in magnetic evoked potentials generated by peripheral nerve stimulation. In clinical applications only transcranial magnetic stimulation is widely used as a tool for motor evoked potentials [16]. The possibility that human laterality is associated with asymmetrical cortical and/or peripheral motor control was previously suggested [23,28]. Taking into consideration these suggestions, significant side asymmetries in magnetically evoked potentials may form evidence for the utility of this technique for motor laterality evaluation. However, the applicability of magnetic stimulation of peripheral nerves in motor asymmetry studies is still unclear. Many technical aspects of magnetic stimulation are reported to influence the results of stimulation; in bilateral studies providing comparative experimental conditions for both sides may be difficult due to the morphological asymmetries of the inner structures. In this experiment we aimed to check the lateral effect of coil polarity on motor evoked potentials in the dominant and non-dominant lower extremity in healthy adults. Data from our experiment are expected to contribute to the standardization of procedures connected with the use of magnetic stimulation in motor control studies focused on lateral asymmetries of motor response.

10 healthy, male volunteers aged 23 ± 6 months and height 186 ± 2 cm with no neurological problems in the past took part in the experiment. All participants were physical education students. All participants were right-handed and right-footed, with no signs of ambidexterity, tested by the use of a handedness and footedness inventory (a selection from the Edinburgh Handedness Inventory by Oldfield [26] with some added questions for foot dominance verified by simple motor tasks, e.g. kicking a ball). The study was approved by the Ethics Committee of the Academy of Physical Education in Katowice and each participant gave informed consent. All participants were unaware of the goals of the experiment to prevent any bias. All experimental sessions were organized in the same laboratory at a stable air temperature of 22 °C, always in the morning (10:00–12:00) to provide comparative experimental conditions for all participants [13,40]. CMAPs from the lateral head of the gastrocnemius muscle of the right and left lower extremity were recorded during magnetic stimulation of the tibial nerve in the popliteal fossa. Participants were lying comfortably on their stomachs, with their heads positioned centrally and arms close to the body.

The Neuro-MS magnetic stimulator used in our experiment was custom-designed by Neurosoft (Neurosoft Ltd., Ivanowo, Russia). The stimulator was synchronized with an EMG recording set. The stimulating coil was circular in design (inner diameter: 5.1 cm; outer diameter 10.2 cm). The magnetic coil was held parallel to the skin with its centre positioned 2–3 cm laterally to the tibial nerve in the popliteal fossa. The coil was held so that one edge was over the branch of the nerve innervating the lateral head of the gastrocnemius muscle, tangentially. Taking into consideration the possibility of side differences in nerve location several trials on each leg were performed before recordings, to find the best stimulation site in the target area of the popliteal fossa (by moving the coil slightly) [33,35]. The coil–skin distance was always tangential to the skin surface to obtain the most comparative magnetic impact on the nerve in both extremities [33]. Two current directions with an opposite orientation in the coil axis were studied: clockwise current direction (CW) and counter clockwise current direction (CCW) – see Fig. 1 for coil placement details. The direction of the coil current was reversed by rotating the coil. Recordings were made by the use of two self-adhesive recording Ag/AgCl electrodes (Sorimex, Poland, diameter 30 mm) placed on the lateral head of the gastrocnemius muscle, symmetrically on the right and left lower extremity. The electrode positions were marked equidistantly from the central lead point on the lead line from the head of the fibula to the heel (tuber calcanei) using the methodology proposed by Zipp [41]. An inter-electrode distance of 40 mm was used to ensure the same position of electrodes on the dominant and non-dominant extremity (see Fig. 1). The ground electrode (a band with a metal wire inside) was placed above the recording site. Before the electrodes were fitted, any body hair was removed and the skin was thoroughly cleaned using an alcohol swab. The grounding band was filled with NaCl. Electrodes were connected to a CYBERAMP 380 differential amplifier with a notch filter. The stimulus intensity was fixed at 40% of the maximal output of the magnetic field (approx. 0.9 T) which was sufficient for eliciting CMAPs with reduced risk of artefacts. We only used low intensity stimuli for all participants, which ensured a painless stimulation and the avoidance of excessive excitation of nearby structures. The EMG recordings included MEPs in the lower limbs as an effect of stimulation time fixed for 1 ms. The left extremity was tested first for all participants. The measurements were repeated 10 times, once every 10 s [37]. Each limb was stimulated for a total of 20 different trials in 2 sets: 10 trials in the CW direction and 10 trials in the CCW current direction. CW and CCW currents were intermixed within each set of trials (reversed after 5 repetitions) to ensure that a prolonged time of stimulation in one direction did not influence the results. After completing all 20 trials this procedure was repeated for the right leg after a 5-min break, to ensure that stimulation of the left leg did not influence the spinal excitability in the right leg.