Electrical activity of the distal muscles of the hand in men having high or low output alpha-frequencies while performing usual manual movements in response to sensory signals

Alevtyna Morenko

Department of Human and Animals Physiology, Lesia Ukrainka Eastern European National University, 13, Voli Street, Lutsk, 43000 UKRAINE

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Corresponding Author:

Alevtyna Morenko, PhD
Tel: +3 066 826 27 23
Email:alevmore@gmail.com

ABSTRACT

Background: Human functional capabilities largely depend upon genetic qualities of person's nervous system. The registration of the spontaneous electroencephalogram (EEG) is among the physiological techniques allowing making a direct estimation of specific features of the nervous system, in particular, the human brain activity. **Purpose:** Research is dedicated to the study of distal muscles of the hand, in particular, its functional ability in men with a high or low background EEG α-frequency being in quiescent state or while performing usual manual movements in response to sensory signals. **Methods:** A test group consisting of 104 healthy men from the ages of 19 to 21 was divided into two groups according to the magnitude of their individual α- frequency (IAF) median – groups with high (n = 53, IA≥10,04 Hz) and low (n = 51, IAF≤10,03 Hz) levels of IAF. Subjects' psychodynamic properties of their nervous processes have been evaluated as well as any background and level of changes in the average amplitude of EMG while performing usual manual movements in response to sensory signals and intergroup differences were studied. **Results:** It has been found that higher levels of speed and accuracy of the sensorimotor response in men with a high IAF are associated with increased lateral and reciprocal significant differences both in the background muscle activity and efficiency of the distal arm muscles primarily functioning as flexors. But on the contrary, the inverse dynamics appears in men having the low-frequency which is correlated with a lower mobility and balanced nervous processes in their sensorimotor response. **Conclusion:** The establishment of such common factors in the experiments groups is an important step towards defining prognostic criteria for the functionality of motor area based on EMG activity of the distal muscles of the hand.

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Introduction

Human functional capabilities largely depend upon genetic qualities of person's nervous system. The registration of the spontaneous electroencephalogram (EEG) is among the physiological techniques allowing a direct estimation of specific features of the nervous system, in particular, the human brain activity. It is believed that its parameters are specified by genetically determined features of the structural and functional organization of the brain.[1–3] The α-rhythm maximum peak frequency has the most information value among its other parameters.[4–6] According to the literature,[7] various α-sub-bands differ specific brain generators, functional significance. A low or high range of the α-rhythm superiority in the background encephalogram of the person can cause his/ her psychomotor and cognitive abilities.[8–10]

Following this line of reasoning, we hypothesized that brain processes in people with different levels of background IAF may be reflected in the muscle activity of the hand. This is due to the pyramidal tract peculiarities whose fibers cause the monosynaptic reflex arising in the motor cortex neurons and transforming to the spinal cord motor neurons innervating the distal muscles of the hand. Thus, to study the functioning of the distal arm muscles (using an electromyography technique) during usual movements carried out by people with a different background IAF is imperative. This study is of theoretical importance as it develops fundamental issues of the human movement neurophysiology as well as of practical use. As can be seen from the above, movements in response to sensory signals create preconditions for the process of the sensorimotor coordination. Their successful implementation is becoming increasingly important in terms of the diversity and complexity of the human information environment now and the distribution of practice concerning the manual remote control by electronic technical devices as well.

Simultaneously, it has been found a lack of information about detected features of the central programming and descending muscle innervations of distal parts of the human hand in men with the different individual α-frequency while performing usual manual movements. Existing data, despite their importance, are inconsistent and insufficient yet.

The purpose of the study was to identify the characteristics of psychodynamic properties of neural processes, the electrical activity of superficial muscles of fingers as indicators of their functional status in a quiescent state and during the performance of usual manual movements in response to sensory signals in subjects with a high or low background rate of α-EEG rhythm.

Methods

The object of the study: The participants in our study were 124 male volunteers from the ages of 19 to 21, each of whom has given written consent. Biomedical ethics rules in accordance with the Helsinki Declaration of the World Medical Association on the Ethical Principles of Scientific and Medical Research involving Human Subjects were adhered to during the experiment. All the subjects were healthy and had normal hearing with regard to the judgment and advisory conclusions of their medical professionals.

Psychophysiological examination: It was determined by the nature of responses in the survey, execution of the motor and psychoacoustic tests and by counting the individual ratio of the manual and auditory asymmetries (K skew) (form. 1).[11]

$$K_{skew} = \frac{\Sigma_{right} - \Sigma_{left}}{\Sigma_{right} + \Sigma_{left}} \times 100\% \qquad \text{Formula 1}$$

where Σ_{right} – the amount of tasks where a right hand (right ear) is dominating during their execution, Σ_{left} – the amount of tasks under which the left hand (left ear) is dominant.

Further studies involved dextral subjects whose coefficients of manual and auditory asymmetries were positive and were above 50%. The total number of men were 104.

The level of psychodynamic properties of subjects' nervous processes were surveyed with a simple sensorimotor reaction taking into consideration time period and sensorimotor responses in the choice of one of three objects as signals (triangles, circles, squares). See the program "Diagnostician -1", Ukraine. All subjects had to respond to the certain stimuli as quickly as possible with pressing of the button by the right hand. Men evaluated and measured time intervals in minutes.

All examinations were performed in the morning. The profile of the asymmetry and psychodynamic properties of neural processes was evaluated 30 minutes before the EEG recording registration.

Registration and initial analysis of EEG: The subjects were in a quiescent state with their eyes closed and in a reclining position with their limbs relaxed and not crossed during the EEG testing. The experiment was carried out in a room which was sound-proof and light-proof. Active electrodes were placed in accordance with the international system 10/20 in nineteen points on the scalp of the head during the electroencephalogram (EEG "Neurocom", and the Certificate of State registration # 6038/2007, valid until 18.04.2014) recording. The performance of the EEG recording was monopolar, with the use of ear electrodes as a reference. The Fourier analysis era was 4 s with a 50% overlap. Duration of sample was 40 s. ICA-procedure analysis was used for the rejection of EEG anomalies.

The maximum frequency peak of the α-rhythm was determined for each subject in each EEG lead at a functional balance.[7] Its value was averaged for all leads and the obtained values were considered as the subject's individual α-frequency (the individual alpha-frequency of EEG, IAF, and Hz). The IAF median was also determined and calculated for the group of men. It was 10.04 Hz. Thus, there were formed subgroups of subjects in according to the value of the median:

- groups with a high IAF (n = 53, IAF≥10.04 Hz);
- groups with a low IAF (n = 51 , IAF<10.04 Hz).

Electromyographic (EMG) testing: The whole experimental procedure consistently included the following steps for each testee:

Step 1. The EEG recording in the functional balance (background)
Step 2. The EEG recording during the clench of the right hand fingers
Step3. The EEG recording during the clench of the left hand fingers

Each step lasted 40 s. To exclude the edge effects, the EEG recording registration was started at 15 s after the beginning and had been stopped at 5 s by its completion.

The execution of each movement of the finger clench and unclench (without any force) was carried out in response to the sound signal. The electronic version of the drum battle (the software of Finale 2006) was used for this purpose. Binaural stimuli were produced by four speakers placed in different corners of the room at the distance of 1.2 m from the subject's right or left ear. The stimulus duration was 130 ms; the playback sound volume did not exceed 55-60 dB at outlet from the speakers under the measurements carried out by the sound level meter of the 'DE-3301' type (certificate of attestation # 025-2009, valid until 21.12.2014). Additionally, the sound loudness was individually regulated for each subject to achieve the necessary level. The rate of the sound stimuli delivery was 2 Hz.

Registration and initial analysis of EMG: The electromyogram (EMG, "Neurosoft", EC-Declaration of Conformity # RQ093102-V, issued by the EUROCAT Institute for Certification and Testing and valid until 07.11.2014) was registered for the superficial flexor muscles (musculus flexor digitorum superfacialis) and the extensor muscles (musculus extensor digitorum) of the right and left hand fingers. A bipolar lead with surface electrodes was used in the EMG recording. The duration of the EMG test was 40 seconds. EMG signals in the off-line regime were processed by means of filtering and amplitude-frequency analysis. High-frequency filters were set at a level of 5 kHz, and low-cut filters at a level of 2 Hz. The band-rejection filter was 50-60 Hz. The epoch of the analysis was 3 s with an ADC frequency request of 10 kHz.

The average amplitude (μV) of the EMG oscillations in superficial muscles of flexors and extensors of fingers was studied in the state of the functional relaxation and calm. The EMG muscle activity and its parameters were elucidated during the performance of tasks dealing with any motor activity and based on the meaningfully increasing average logarithmic amplitude of EMG oscillations in comparison with the functional state of relaxation and calm (Formula 2):

$$L = 20 \cdot \lg e_2/e_1 \text{ (dB)}, \qquad \text{Formula 2}$$

where e_1 - the average amplitude of EMG at rest and e_2 - the average amplitude of EMG oscillations while performing any movements.

The use of such quantitative indicators of the muscle activities is due to significant differences in the magnitude of the average data error when subjects are in a quiescent state or while performing manual movements.

Statistical analysis of the results: A statistical data analysis was performed by using the package 'STATISTICA 6.0'. Any normalcy of the data distribution in subjects' subgroups was evaluated by means of the Shapiro - Wilks test (indicator SW). Based on test results, it was found that all of our studied samples had a normal data distribution. To estimate the significance of differences existing in subjects' subgroups, the Student's *t*-test (index t) was used between steps of testing both for independent equal samples and for dependent samples. Significant differences between subjects' subgroups and among steps of testing were statistically considered at $p \leq 0.05$ and $p \leq 0.001$.

Table 1: Simple with Choice Sensorimotor Reaction Latency in the Surveyed Subgroups (sec)

Groups / Indeces	Simple reaction time		Choice reaction time	
	Men with a high IAF	Men with low IAF	Men with a high IAF	Men with low IAF
Reaction time	232.35 ± 5.15	299.21 ± 6.40**	334.82 ± 7.19	399.9 ± 15.29**

Table 2: Estimation and Constant Time-Step Advancement in Minutes in Subjects' Subgroups (%)

Groups / Indeces	Men with a high IAF	Men with low IAF
Overestimation of measured timeslots	14.60	24.00
Accurate estimation of measured timeslots	65.40	56.00
Underestimation of measured timeslots	20.00	20.00

Results

Psychodynamic properties of neural processes in the subjects' groups with different levels of IAF: Taking into consideration the sexual aspect, the male subjects with a high IAF spend less time both for a simple sensorimotor coordination and any choice reaction ($p \leq 0.001$) (Table 1). The analysis and evaluation of metering minute time intervals indicate that the subjects having a high IAF are characterized by more accurate estimation of time (Table 2) than others. Moreover, men with a low IAF have relatively higher overestimation as well as incompletely measured timeslots.

The muscle electrical activity of the hand at rest (subgroups of men): The resting muscle tone of each subjects' right hand is provided with a significant predominance of the EMG average amplitude of its extensor muscles ($p \leq 0.001$) (Figure 1). The significance of the regularity is higher in men with a high IAF than in others.

The resting muscle tone of the male left hand in each men is accompanied with the increase in the EMG amplitude of the flexor ($p \leq 0.05$) in comparison with the right hand. Such common factors are complemented with a relative decrease in the amplitude of the extensor muscles ($p \leq 0.05$) in men with a high IAF. This subgroup is not characterized by differences in indicators of antagonist muscles of the left hand but the EMG amplitude of the extensor prevails in men with a low IAF. It is less important than in case of extensors of the male right hand ($p \leq 0.05$) (Figure 1).

Being in the quiescent state, men with a high IAF have higher amplitude of the extensor muscles of the right hand and left hand flexors ($p \leq 0.05$) than the surveyed with a low IAF (Table 3).

Electrical activity of the distal muscles of the hand while performing motor tasks by subgroups of men. An average increase in the EMG amplitude of flexor and extensor muscles is registered in each testee in comparison with cases when subjects'

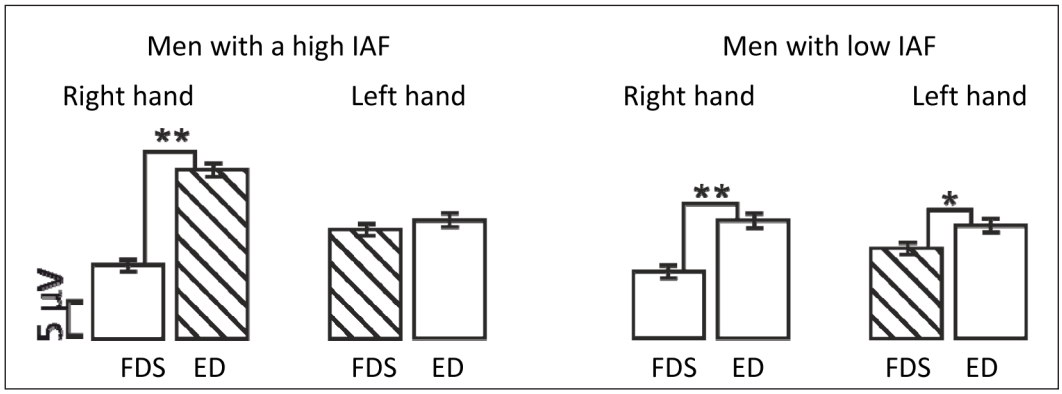

Fig. 1: Measures of the average amplitude of EMG oscillations (mV) of the superficial flexor muscles (musculus flexor digitorum superfacialis, FDS) and extensor muscles (musculus extensor digitorum, ED) fingers in the group of subjects.

Table 3: Measures of EMG Oscillations (M±m) and Their Average Amplitude as to Superficial Muscles in Case of Clenching and Unclenching Fingers by Subjects in Their Subgroups

Subgroups / Muscles	Men with a high IAF		Men with low IAF	
	Right hand muscles	Left hand muscles	Right hand muscles	Left hand muscles
Flexors	10.37 ± 0.74	15.26 ± 1.03*	10.14 ± 0.92	12.75 ± 0.95
Extensors	23.7 ± 2.00*	16.54 ± 1.25	16.65 ± 1.59	15.95 ± 1.82

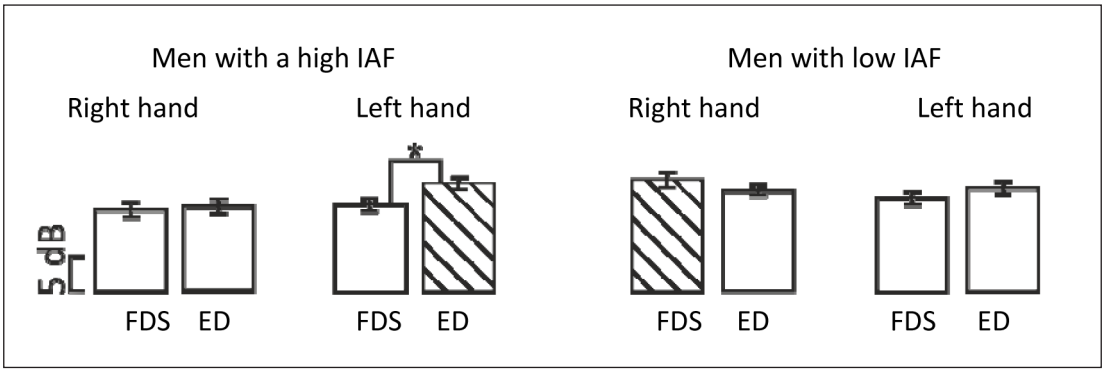

Fig. 2: The EMG activity of the superficial flexor muscles (musculus flexor digitorum superfacialis, FDS) and extensor muscles (musculus extensor digitorum, ED) of the right and left hand fingers in male groups.

Table 4: The EMG Activity (dB, M ± m) of Superficial Muscles of Fingers in Subjects' Subgroups Performing Movements by Their Fingers

Subgroups / Tests	Men with a high IAF		Men with low IAF	
	Flexors	Extensors	Flexors	Extensors
Right hand movements	11.75 ± 0.89	12.08 ± 0.80	15.85 ± 0.99*	14.32 ± 0.71*
Left hand movements	12.60 ± 0.81	15.51 ± 0.66	13.32 ± 0.73	14.86 ± 0.62

are in quiescent states (Figure 2). Reciprocal differences of the right hand muscles are not found in men with a high IAF. But higher values of EMG activity of the extensor muscles of the left hand ($p \leq 0.05$) are recorded. Men of this subgroup have a higher EMG activity of extensor muscles in the left hand compared to the right ones ($p \leq 0.05$).

Reciprocal differences of muscles in both hands are not fixed in men with a low IAF. The EMG activity of the right hand flexor is greater than the left one ($p \leq 0.05$).

Subjects with a low IAF are characterized by a gr eater EMG activity of flexors and extensors ($p \leq 0.05$) when motor tasks are done with right hand, and intergroup difference has not found in comparison with individuals having a high IAF and performing motor tasks with their left hand (Table 4).

Discussion

Subjects with a high IAF are characterized by a higher speed performance of the neuro-motor apparatus in terms of both simple sensorimotor and choice reactions requiring the involvement of associative processes, re-encoding of information, and complex inter-system interactions. Men of this subgroup are also characterized by a more accurate estimation of time, which may indicate an increase in balance of nervous processes of the excitation and inhibition.[8] Long-term observations of researcher Elkin D. G.[12] show a direct correlation between the perception of time and the activities: the more accurate perception of time, the more successful activities are. Men with a low IAF have relatively higher rates of the overestimation and incompletely measured minute intervals (timeslots). Thus, it may indicate a predominance of neural inhibitory processes. Such psycho-dynamic properties of the nervous system due to the predominance of the low- or high-frequency ranges of the baseline EEG and its α-rhythm has created a decisive influence on the specifics of the electrical activity of the distal muscles of the hand in the quiescent state and during usual manual movements.

All of the subjects in the quiescent state are characterized by the increased extensor tone of the right hand leading to a reciprocal decrease in the flexor tone. The resting muscle tone of the left hand has a higher flexor tension. The value of the lateral differences (between muscle activity on the right and left hands) and reciprocal (muscle activity between flexors and extensors) is higher in men with a high α-frequency than in men with a low IAF.

An increase of the EMG activity of muscles is registered In case of finger movements carried out by subjects. According to the literature,[13,14] an increase in the number of their active DE and as a consequence of their muscle force may be caused. Performing manual motor movements with a right hand is accompanied by a relatively higher EMG activity of the flexor muscles in men with a low IAF. We suggest it may reflect the greater activity of the motor cortex during these movements with the right hand as well as lead to the increase in growth of the average amplitude of the EMG of flexor muscles. Performing movements with a left hand it complicates both programming and performing movements. Descending influences may have the inhibitory nature and down the contractile activity of the flexors.

A large increase of the muscle tone in the extensors of the subjects with a high IAF is registered in case of movements performed by the left hand than in the extensors of subjects having a low IAF. The increase of the tension and "fixity" of movements made by the left (non-dominant) hand is present and it increasingly reduces the contractile activity of the flexor muscles in the subgroups of subjects with a high IAF.

The established regularities in muscle activities of the right and left hands may indicate an increase in the efficiency of the

distal muscle activities of the hand, mostly flexors both in the quiescent state and during the implementation of the manual motility in men with a high IAF.

Conclusions

Higher rates of the speed and accuracy of the sensorimotor responses in men with a high IAF are associated with the increased lateral and reciprocal significant differences in the background muscle activity, efficiency and functionality of distal muscles in hands, primarily, flexors both in the quiescent state and while performing usual manual movements. But the opposite dynamics correlating the nervous processes with lower mobility and balance in the sensorimotor response is present in men with a low IAF.

The establishment of such common factors in the studied groups is an important step towards definition of the clear prognostic criteria for the functionality of men in the fine motor area according to the EMG activity of the distal muscles of the hand.

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