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SEXUAL CHARACTERISTICS OF INTERCORTICAL RELATIONSHIPS IN THE DELTA RANGE OF THE POWER SPECTRUM WHEN PERFORMING ARBITRARY BIMANUAL PURPOSEFUL MOVEMENTS

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Abstract. The level of bimanual coordination in men and women is represented by different effectiveness, which is explained by the peculiarities of the organization of the sensorimotor sphere in women and men. The processes of excitation and inhibition are complementary and contribute to the effective construction of the motor system. The aim of the study is to study the sexual characteristics of cortical activation in the delta range and to identify intersystem cortical relationships in the implementation of complexly coordinated bimanual movements. The level of brain activity was assessed by recording the delta rhythm during electroencephalography, and the results of the coordination index using the method of supportmetry. Significant differences in the inhibitory activity of the cerebral cortex and the functional relationships of its centers have been revealed, which causes differences in the resulting effectiveness of motor programs. In the female group, high activity in the delta range of the left frontal associative cortex and a pronounced connection between the occipital and premotor regions on the right are of leading importance in the formation of the motor program. In men, hemispheric asymmetry with inhibition of the right hemisphere contributes to a more perfect result.

Keywords: voluntary motor activity, electroencephalography, bimanual coordination, cortical activity

ПОЛОВЫЕ ОСОБЕННОСТИ МЕЖКОРКОВЫХ СВЯЗЕЙ В ДЕЛЬТА-ДИАПАЗОНЕ СПЕКТРА МОЩНОСТИ ПРИ ВЫПОЛНЕНИИ ПРОИЗВОЛЬНЫХ БИМАНУАЛЬНЫХ ЦЕЛЕНАПРАВЛЕННЫХ ДВИЖЕНИЙ

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Резюме. Уровень бимануальной координации у лиц мужского и женского полов представлен разной результативностью, что объясняется особенностями организации сенсомоторной сферы у женщин и мужчин. Процессы возбуждения и торможения являются взаимодополняющими и способствуют эффективному построению двигательной системы. Целью исследования является изучение половых особенностей активации коры в дельта-диапазоне и выявление внутрисистемных корковых взаимосвязей при реализации

сложноскоординированных бимануальных движений. Уровень активности мозга оценивался регистрацией дельта-ритма при проведении электроэнцефалографии, а результаты показателя координации — с помощью метода суппортметрии. Выявлены достоверные различия в тормозной активности коры больших полушарий и функциональных взаимосвязях ее центров, что обусловливает различия результирующей эффективности выполнения моторных программ. В женской группе ведущее значение в формировании моторной программы имеет высокая активность в дельта-диапазоне левой фронтальной ассоциативной коры и выраженная связь затылочной и премоторной области справа. У мужчин межполушарная асимметрия с торможением правого полушария способствует более совершенному результату.

Ключевые слова: произвольная двигательная активность, электроэнцефалография, бимануальная координация, корковая активность

INTRODUCTION

Sex differences in motor functioning do not cause doubts among modern researchers [1, 5, 8, 11, 15], but the nature of these differences is still insufficiently studied. Rhythmic bimanual movements are represented in the central nervous system as a motor program of their tact, within which a strategy of locomotion execution is formed [10, 12]. Activity of various centers of cerebral hemispheric cortex and their interrelation are a leading factor in initiating and correcting engrams of movements [3, 5, 7, 15]. Excitation and inhibition processes are complementary and contribute to effective construction of a motor system [1, 9, 16]. A commonly accepted technique for recording the electrical activity of the brain — electroencephalography — makes it possible to record slow waves in a delta-band and assess inhibition of cortical areas of large hemispheres [4].

AIM

The aim is to examine sex-specific features of cortical activation in the delta band and to identify intrasystem cortical interconnections in realizing coordinated complex bimanual movements.

MATERIALS AND METHODS

The research was conducted in the laboratory of physiology of motor activity of the Research Institute of Physiology, united with the single-profile department of the Federal State Budgetary Educational Institution of Higher Professional Education “Kursk State Medical University” of the Ministry of Health of Russia.

53 men and 51 women aged 18 to 24 years took part in the experiment on the basis of informed voluntary consent. Participants had to undergo an assessment of bimanual coordination by means of suportmetry [10]. As part of this method, participants had to perform four tasks of varying difficulty; the results were used to evaluate time required to perform a task, number of errors, time spent in and out of the task contour, as well as to calculate an integral index of coordination. Then, after completing the tasks, electroencephalogram was recorded for 2 minutes. A «10–20» international system of electrodes was used for recording, within which activity from 21 calyx electrodes was recorded. The data obtained from electrodes Fp1-A1, Fp2-A2, C4-A2, C3-A1, T3-A1, T4-A2, O1-A1, O2-A2 were used, since these electrodes reflect activity of main cortical areas responsible for movements.

Electrode impedance did not exceed 20 kOhm, sensitivity was established at 7 μV/mm. Further computer processing of a signal was carried out by the fast Fourier transform method, with no fewer than 30 epochs of 2 s averaging [4, 6].

An electroencephalograph-analyzer EEGA-21/26 “Encephalan-131–03” (Taganrog, Russia) was used in the experiment. Statistical processing was performed by comparing mean values of a power spectrum in two groups. Quantitative indices were evaluated for conformity to normal distribution using the Kolmogorov-Smirnov criterion (when the number of subjects was more than 50). If there was no normal distribution, quantitative data were described using median (Me), lower and upper quartiles (Q1–Q3). Categorical data were described with absolute values and percentages [2].

RESULTS

The lowest values were recorded in C3-A1 leads when comparing the parameters in delta range (Table 1) in women. Values in T3-A1 were higher by 13%, in Fp1-A1 by 29%, in T4-A2 by 51%, in O2-A2 by 67%, and in Fp2-A2 by 79%. Mean values in O1-A1 are 9% higher than the median in C3-A1 and 63% higher in C4-A2. The highest value is in Fp2-A2. The lowest value of the power spectrum in men was registered in C3-A1. The values in T3-A1 are higher by

Table 1

The average values of the EEG power spectrum in the delta range in women and men when performing arbitrary bimanual purposeful movements

Таблица 1

Средние показатели спектра мощности ЭЭГ в дельта-диапазоне у женщин и мужчин при выполнении произвольных бимануальных целенаправленных движений

Группа / Group	Отведение энцефалограммы / Electroencephalogram leads							
	Fp1-A1	Fp2-A2	C3-A1	C4-A2	O1-A1	O2-A2	T3-A1	T4-A2
Женщины / Women	8,31 (Me)	11,56 (Me)	6,45 (Me)	10,49±9,73 (M±SD)	7,03±3,93 (M±SD)	10,80 (Me)	7,28 (Me)	9,72 (Me)
Мужчины / Men	9,43 (Me)	11,83 (Me)	8,62 (Me)	11,36±7,54 (M±SD)	10,85±6,46 (M±SD)	13,58 (Me)	8,68 (Me)	9,95 (Me)

Note: M — the average value; SD — the standard deviation; Me — the median.
Примечание: M — среднее значение; SD — стандартное отклонение; Me – медиана.

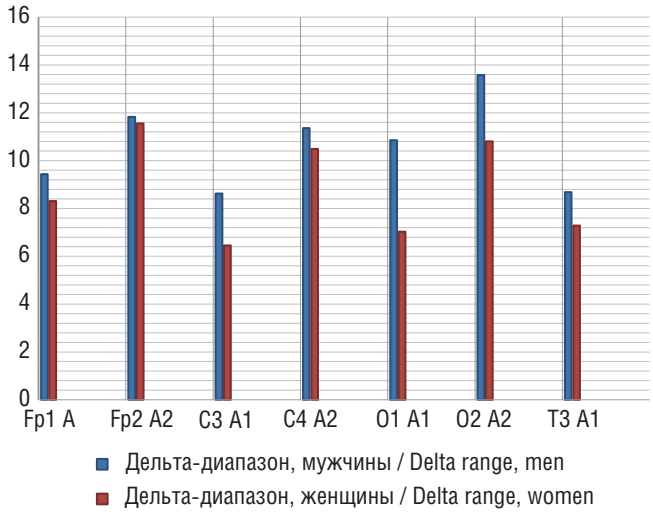

Fig. 1. Comparative characteristics of the average values of the EEG power spectrum in the delta range in women and men when performing arbitrary bimanual purposeful movements

Рис. 1. Сравнительная характеристика средних показателей спектра мощности ЭЭГ в дельта-диапазоне у женщин и мужчин при выполнении произвольных бимануальных целенаправленных движений

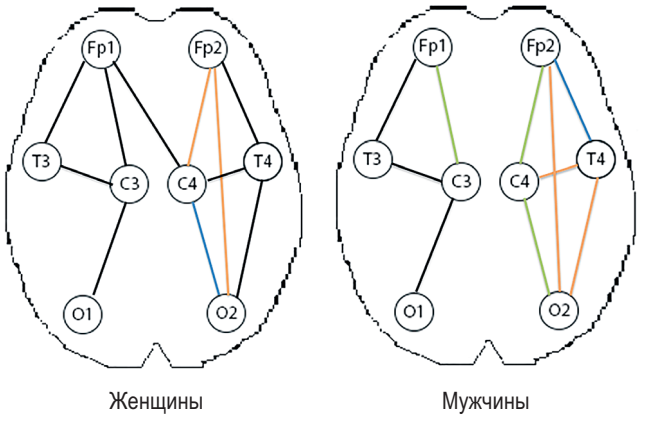

Fig. 2. Correlation pleiades of the power spectrum of female and male subjects in the delta range when performing arbitrary bimanual purposeful movements

Рис. 2. Корреляционные плеяды спектра мощности испытуемых женского и мужского пола в дельта-диапазоне при выполнении произвольных бимануальных целенаправленных движений

1%, by 9% in Fp1-A1, by 15% in T4-A2, by 37% in Fp2-A2, and by 56% in O2-A2. Mean value in C4-A2 is 26% higher than median in O1-A1, and 32% higher in C3-A1. The maximum value was detected in O2-A2, indicating high delta activity in the occipital lobe on the right side.

Comparative analysis of mean values female and male groups (Fig. 1) showed that Fp1-A1 reflects left frontal lobe activity. Values in the male study group were 13% ($p < 0.001$) higher than in the female group. Fp2-A2, showing functioning of the right frontal lobe, were 2% ($p < 0.001$) higher in males. C3-A1 (projection of the central premotor cortex on the left) is 34% higher ($p < 0.001$). C4-A2 which is the projection of the central premotor cortex on the right, is 8% higher ($p < 0.001$). O1-A1 shows functioning of the left occipital region, and appears to be higher by 54% ($p < 0.001$). O2-A2 (the right occipital region) is higher by 26%, T3-A1, the left temporal region projection, is higher by 19%, and T4-A2, the right temporal region projection, is higher by 2% ($p < 0.001$). Comparative analysis of a power spectrum in delta-band revealed predominance of brain activity in all areas in males compared to females.

When conducting correlation analysis between brain activity indices in delta-band of a power spectrum in males, the absence of interconnections between left and right hemi-

spheres is observed (Fig. 2). At the same time, the density of connections is higher in right brain areas. In women, the connection between the right and left hemispheres is provided by interaction between the left frontal cortex on the left and the central premotor cortex on the right. At the same time, the connection strength in male group in Fp2-A2 — C4-A2 is 15% higher ($p < 0.001$), in T4-A2 — O2-A2 is 17% higher ($p < 0.001$), in Fp1-A1 — C3-A1 is 34% higher ($p < 0.001$), in Fp2-A2 — T4-A2 is 34% higher ($p < 0.001$). C4-A2 — O2-A2 was 14% higher in women ($p < 0.001$). The central premotor area on the right side is the multipolar center, it has the highest value of a total correlation coefficient in women. Similarly, it has bilateral correlations of high density together with the occipital region on the right side. Central premotor cortex on the right is also the area of high correlation with the maximum value of a total coefficient in men. However, correlations of high density are located between the frontal associative cortex on the right and the right temporal area.

DISCUSSION

The delta rhythm has a thalamocortical nature [4], and indicates inhibitory activity of specific thalamic nuclei due to mirror neurons located in the cortex [9], reflecting processes of memory consolidation and cognitive activity [7, 15, 17]. Since motor activity is a combination of excitation and inhibition processes, this rhythm will have a significant effect on implementing motor programs [1, 9, 16]. Maximum activity in the left frontal lobe in women can indicate deep inhibition processes of tertiary motor fields of the associative cortex on the left. At the same time, a bridge between the left and right hemispheres, which is located between the left frontal lobe and the central premotor cortex, may account for lower indicators of bimanual coordination in women compared to men. The pronounced association between occipital and central premotor areas on the right may have an inhibitory effect on retrieval processes of existing engrams from memory.

The male group is characterized by higher delta-band activity in all electrodes, indicating a deeper inhibition of structures. Mapping of functional connections in this group allows us to suggest the absence of mutual influences between the hemispheres and a pronounced right-sided asymmetry of activity. The bilateral connection of high density between frontal and temporal lobes on the right can speak about mutual inhibition of tertiary motor fields of frontal associative cortex and vestibular centers on the right. Thus, under the conditions of suportmetry tasks performance, it has a positive influence on a better result.

Bimanual coordination indices have significant differences in women and men, thus confirming previously obtained data [11, 13]. Results differ due to distinctions in tactics during task performance. Thus, there are differences in initiation and correction of motor programs in cortex [12, 14]. Registration of delta brain activity allows us to evaluate inhibition of centers involved in movement. The female group is characterized by active inhibition of the left frontal associative cortex, the presence of a “bridge” linking the hemispheres in the left frontal and right central premotor areas, and pronounced connections between the central premotor and occipital cortex on the right side, which together shows a less effective strategy for performing a motor act compared to men. Delta activity is more pronounced in men and indicates deeper inhibition in all cortical centers. The absence of connections between hemispheres with pronounced right-sided asymmetry of activity and mutual suppression of temporal and frontal areas on the right reflects a more efficient process of bimanual coordination.

CONCLUSION

1. Women and men revealed different strategies for performing arbitrary bimanual goal-directed movements.

2. Females have high activity in the delta-band of the left frontal associative cortex and pronounced association of the occipital and premotor areas on the right side which influences the formation of motor programs.

3. Interhemispheric asymmetry in men inhibits the right hemisphere and contributes to a better motor functioning.

ADDITIONAL INFORMATION

Author contribution. Thereby, all authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

Competing interests. The authors declare that they have no competing interests.

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Consent for publication. Written consent was obtained from the patient for publication of relevant medical information within the manuscript.

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Вклад авторов. Все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией.

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

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