Interhemisphere asymmetry of the dominant frequency of electroencephalogram rhythms with age

Z. A. Magomedova*, and *S. S.* Abumuslimov

Kadyrov Chechen State University, Grozny, Russia

Abstract. The work investigated the asymmetry of the dominant frequency of electroencephalography (EEG) rhythms in the two hemispheres of the brain. Three age periods were studied: 16-20, 21-35 and 35-60 years. The study of the dominant frequency was carried out in general groups and separately in males and females. Students, additional education students and university staff were recruited as subjects. The dominant frequency of EEG rhythms was studied using a Neuron-Spectrum 1 electroencephalograph in eight monopolar leads. Electrodes were applied to the scalp according to the international "10-20%" system. The subjects' electroencephalograms were recorded in a state of wakefulness with their eyes closed. The dominant frequency of five EEG rhythms was studied: alpha, beta1, beta2, theta and delta rhythms. It was revealed that at different age periods in general groups there is asymmetry in individual EEG rhythms. In addition, when studying males and females separately, asymmetry in the dominant frequency is observed in them at different age periods. Our data indicate a possible asymmetry in the electrical activity of the cerebral hemispheres in humans aged 16 to 60 years.

1 Introduction

Interhemispheric asymmetry is an innate property of the human brain. During ontogenesis, the profile of interhemispheric asymmetry can change, since the specialization of the hemispheres can be improved under the influence of social factors [1]. Hemispheric asymmetry depends not only on age, but also on the influence of environmental factors, hormonal status and biochemical characteristics of cellular processes in the cerebral hemispheres.

The existence of structural and psychophysiological differences between the right and left hemispheres has been shown [2, 5]. Thus, according to psychophysiological studies, the right hemisphere is responsible for the spatial functions of the brain, and the left hemisphere determines the verbal (speech) functions of the brain. With the dominance of the left hemisphere, a person is distinguished by a high vocabulary, increased motor activity, and with the right hemisphere, the person is slower, less talkative, more

*Corresponding author: magomedova1204@mail.ru

predisposed to contemplation and has a more subtle sensitivity. In the left hemisphere, the process of analyzing perceived information is first carried out, only then the process of synthesizing information. In the right hemisphere, on the contrary, the process of synthesis is realized first, then analysis. The right hemisphere occupies a dominant position during emotional activity and in imaginative thinking. In right-hemisphere people, concrete thinking predominates. The left dominates when performing abstract activities [Antropova]. At the same time, there is genetic research that states the absence of interhemispheric asymmetry. This work was carried out on large samples [9].

The problem of interhemispheric asymmetry is very relevant in neurobiology and psychophysiology. Clarification of the anatomical and functional organization of the hemispheres contributes to the understanding of the complex mental and psychophysiological mechanisms of the hemispheres and their interaction [2, 5].

Specialization of the functions of the hemispheres is an important factor in the process of adaptation to the external environment and determines the effectiveness of work and educational activities.

One of the methods for assessing functional interhemispheric asymmetry of the brain is electroencephalography. Data regarding the bioelectrical activity of the two hemispheres are contradictory and not systematized. In most studies, EEG studies of the two hemispheres do not show significant differences. In particular, differences in the electrical activity of the hemispheres were found in one of the EEG rhythms – the amplitude of the alpha rhythm [4].

Age-related changes in the general electrical activity of the two hemispheres and functional asymmetry in adolescence and adulthood have been little studied. The frequency of EEG rhythms is often studied in electroencephalographic studies. Modern electroencephalographs such as Neuron-Spect-1 calculate, in addition to the average, the dominant frequency. It has been little studied.

Purpose of the work: Study of the asymmetry of the dominant frequency of EEG rhythms in the two hemispheres in individuals of adolescence and adulthood.

2 Research Methodology

The work examined the dominant frequency of EEG rhythms in different age periods of a person. The study was conducted in three age groups: 16-20 years - adolescence; 21-35 years – mature age, first period and 35-60 years – mature age, second period.

The groups were formed from among employees, students of additional education, female students and male students of ChSU named after. A. A. Kadyrova.

Those involved in the study had no complaints of diseases of the central nervous system or brain injuries.

Each age group included ten people, of which five were female and five were male.

The EEG study was carried out using an electroencephalograph "Neuron-Spectrum 1". The electroencephalograph is automated, connected to a computer, and the recorded electroencephalogram is displayed on the computer monitor. Quantitative indicators of the electroencephalogram are automatically calculated by the EEG program. In particular, among the calculated parameters of EEG rhythms is the rhythm frequency. Rhythm frequency is expressed as the number of vibrations per second. The work examined the dominant frequency calculated by the Neuron-Spectrum-1 software. Dominant frequency is the most frequently occurring rhythm frequency.

Electrodes were applied to the subject's head according to the international "10-20%" system. The number of applied electrodes for EEG analysis during the electroencephalographic study was eight. This is a standard installation. During EEG recording, the overhead lighting in the room was turned off. The subject with the electrodes

on, located on a chair, closes his eyes during EEG recording, but is in a state of wakefulness. EEG recording was carried out automatically for two minutes.

Statistical processing of experimental data was carried out using the Biostatistics program using the Student's test.

3 Results and Discussions

Asymmetry of the dominant frequency of EEG rhythms in adolescents. Studying age-related changes in the asymmetry of the dominant frequency of the main EEG rhythms was the goal of our study. The results of the comparison of the dominant frequency in adolescents are presented in Table 1 and Figure 1. As can be seen from the presented data, the dominant frequency of many EEG rhythms in the general group did not change. However, one of the studied rhythms shows a significant decrease. This is a high-frequency beta2 rhythm; its dominant frequency decreased significantly in adolescents (21-35 years old) (Table 1, Fig. 1). Some other rhythms, alpha and beta-1, also show a downward trend. In the other two rhythms, the dominant frequency, on the contrary, increases unreliably. We obtained these results by comparing the general group of adolescents. Thus, there are minor significant interhemispheric differences in the electrical activity of the two hemispheres. The existence of interhemispheric asymmetry of the human brain is evidenced by data in the literature [3, 4].

Table 1. The dominant frequency (Hz) of EEG rhythms in the two hemispheres in adolescents. General group

Hemisphere	α	β1	β2	θ	σ
Left	10,4±0,22	16,4±0,31	23,5±0,42	5,3±0,23	0,79±0,10
Right	10,1±0,16	16,2±0,37	22,3±0,33*	5,6±0,25	0,84±0,07

*- p<0,05

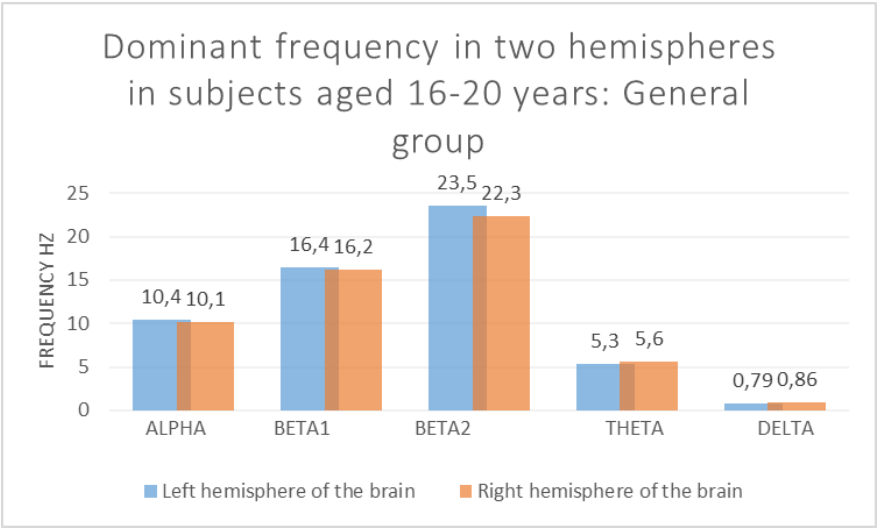

Fig. 1. Dynamics of the dominant frequency in adolescents: general group. Subjects are not divided by gender

When comparing the dominant frequency in the two hemispheres in adolescents, taking into account gender, we obtained the following data. In young men, there are practically no significant interhemispheric differences in the dominant frequency (Table 2, Fig. 2). The

frequencies of some rhythms—alpha and theta—in the right hemisphere show higher absolute values. Thus, in young men (adolescence), there is no interhemispheric asymmetry in the dominant frequency. It should be noted that the literature contains rather contradictory data regarding interhemispheric brain asymmetry in males [8, 10]. According to these authors, interhemispheric asymmetry in girls is registered before the age of 13, and in boys from the age of six, that is, gender affects brain asymmetry. At the same time, other authors point out that sex differences are not associated with genetic belonging to one sex or another, but with the rate of development of the central nervous system and brain [7].

Table 2. Dominant frequency in the two hemispheres in young men

Hemisphere	α	β1	β2	θ	σ
Left	9,8±0,21	16,2±0,51	22,8±0,53	5,0±0,28	0,99±0,126
Right	10,1±0,19	16,4±0,48	22,4±0,56	5,3±0,36	0,97±0,114

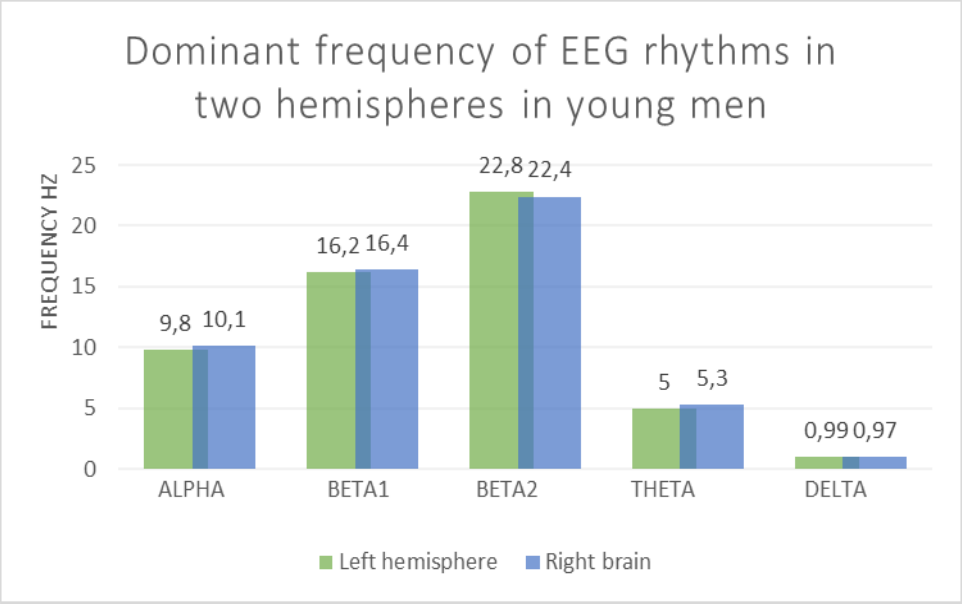

Fig. 2. Comparison of the dominant frequency in two hemispheres in adolescent students.

In girls, interhemispheric asymmetry was revealed by high-frequency beta-2 rhythm and delta activity (Table 3, Fig. 3). As you can see in the table and histogram, the high frequency of the beta2 rhythm in female students is observed precisely in the left hemisphere. In the same hemisphere, the dominant frequency of the delta rhythm was significantly reduced in girls.

Table 3. Dominant frequency in the two hemispheres in girls.

Hemisphere	α	β1	β2	θ	σ
Left	10,8±0,37	16,7±0,41	24,2±0,34	5,4±0,23	0,56±0,03
Right	10,3±0,26	16,1±0,52	22,2±0,32**	5,6±0,25	0,71±0,04**

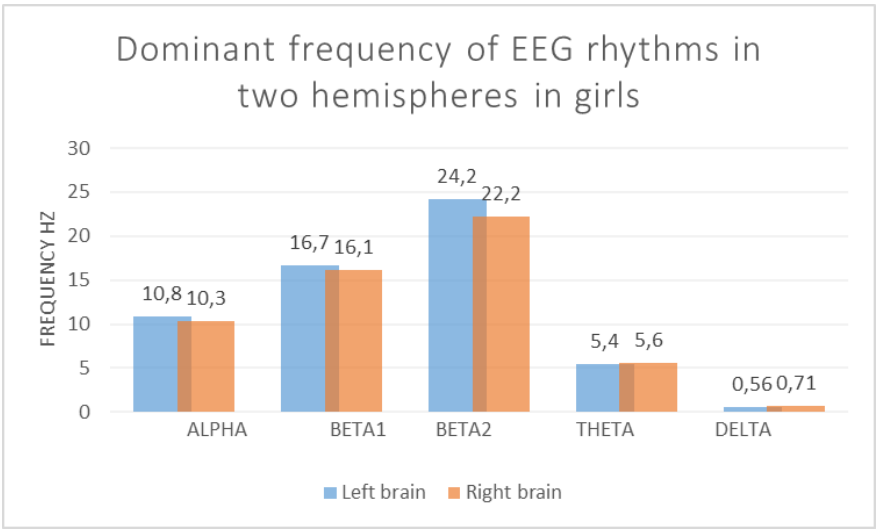

Fig. 3. Comparison of the dominant frequency in the 2 hemispheres in adolescent girls.

Thus, in adolescence, interhemispheric asymmetry is noted in females, while in the opposite sex it is not expressed. In young men there are minor differences in the magnitude of the dominant frequency, but they do not reach statistical significance. Differences between boys and girls are explained by gender. Sex hormones affect the brain, in particular, they affect the excitability of neurons and metabolic processes in them. The rate of brain maturation depends on gender [7]. EEG patterns are influenced by the training of sensory, motor, speech and other brain functions.

Interhemispheric asymmetry of the dominant frequency in persons of mature age, the first period. As can be seen from the results of our study in the first period of adulthood (Table 4, Fig. 4), interhemispheric asymmetry is mainly absent in the general group. Only the low-frequency beta1 rhythm showed asymmetry in the examined patients. In the right hemisphere, the dominant frequency of this rhythm was significantly higher in subjects in the general group.

Table 4. Asymmetry of the dominant frequency (Hz) of rhythms in individuals aged 21-35 years.
General group

Hemisphere	α	β1	β2	θ	σ
Left	9,7±0,31	15,1±0,29	24,4±1,10	4,8±0,30	0,95±0,085
Right	9,5±0,29	16,0±0,28*	23,4±0,58	5,1±0,31	0,81±0,084

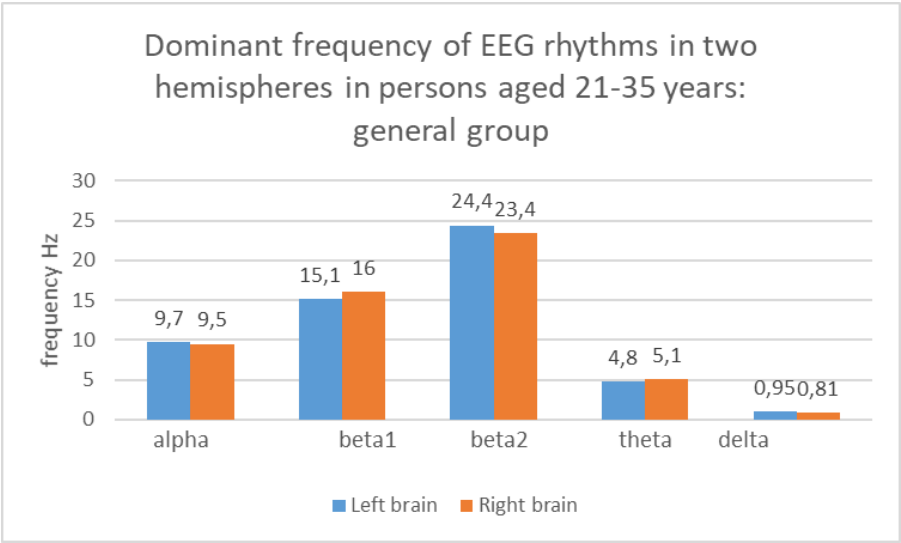

Fig. 4. Interhemispheric frequency asymmetry in individuals aged 21-35 years: general group

When examining the dominant EEG frequency separately, in men brain asymmetry was detected in only one - the beta-1 rhythm, and was absent in the other rhythms (Table 5, Fig. 5). Thus, at this age, in males, we recorded differences between the hemispheres. Based on literature data, it can be assumed that the asymmetry of the hemispheres in men is probably due to the functional specialization of the hemispheres.

Table 5. Interhemispheric asymmetry of the dominant frequency (Hz) of EEG rhythms in men aged 21-35 years

Hemisphere	α	β1	β2	θ	σ
Left	9,9±0,27	15,7±0,30	23,9±1,05	5,1±0,61	1,1±0,11
Right	9,1±0,23*	16,9±0,31*	23,4±1,21	5,5±0,56	0,9±0,12

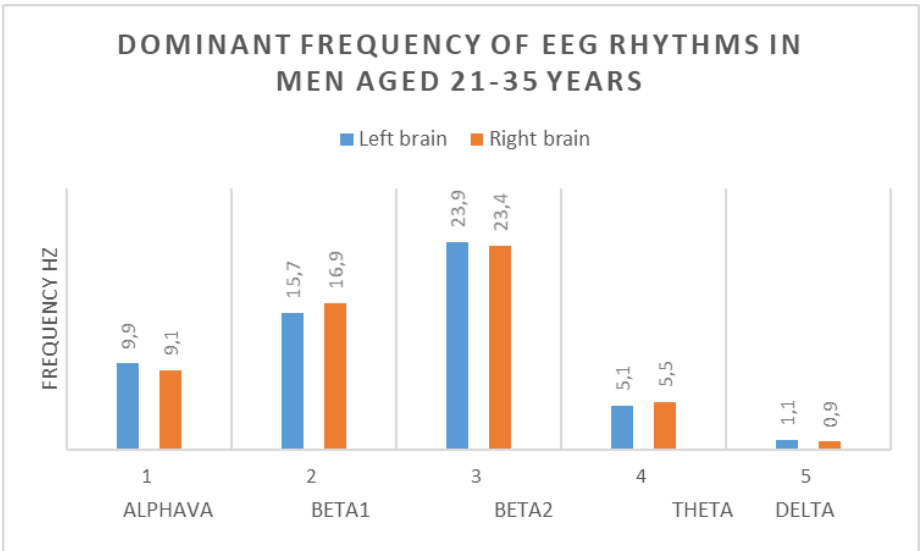

Fig. 5. The dominant EEG frequency in two areas of the brain in men of the first period of adulthood

In females of this period we see the absence of interhemispheric differences (Table 6; Fig. 6). In women, most brain maturation occurs during adolescence, but the process appears to slow down in later life.

Table 6. Asymmetry of the dominant frequency (Hz) of EEG rhythms in the two hemispheres of the brain in women aged 21-35 years.

Hemisphere	α	β1	β2	θ	σ
Left	9,6±0,36	15,8±0,53	24,7±0,91	4,5±0,25	0,80±0,09
Right	9,4±0,34	15,4±0,38	23,4±0,55	4,7±0,28	0,77±0,13

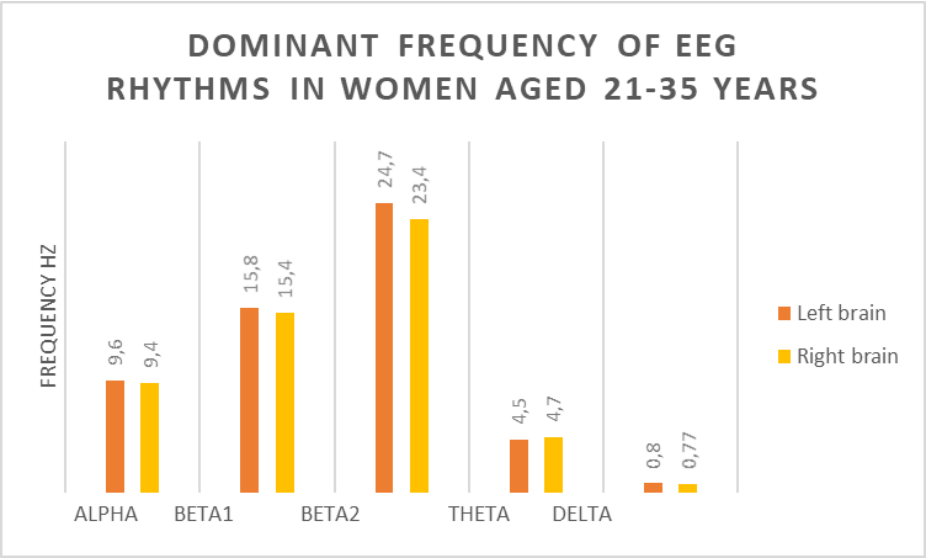

Fig. 6. Frequency distribution of EEG rhythms in two areas of the brain in women aged 21-35 years

Thus, minor interhemispheric differences in electrical activity occur between the ages of 21 and 35 years. For many rhythms, no asymmetry was detected. Only in males did we record differences in hemispheres during this age period.

Interhemispheric differences in the dominant frequency of EEG rhythms in persons of mature age, second period. In the second period of adulthood, our subjects in the general group did not have statistically significant interhemispheric asymmetry of many rhythms (Table 7, Fig. 7). However, the absolute values of the frequency of alpha, beta1, and theta rhythms are higher, which indicates greater functional and electrical activity of the left hemisphere. This may be due to the fact that the left hemisphere is more often in demand under high mental load. This age was represented by university staff.

Table 7. Dominant frequency (Hz) of rhythms in the left and right hemispheres in persons aged 35-60 years: general group

Hemisphere	α	β1	β2	θ	σ
Left	10,2±0,21	15,6±0,36	20,8±0,43	5,6±0,17	0,85±0,09
Right	9,6±0,18	15,1±0,33	20,7±0,44	5,2±0,16	0,85±0,08

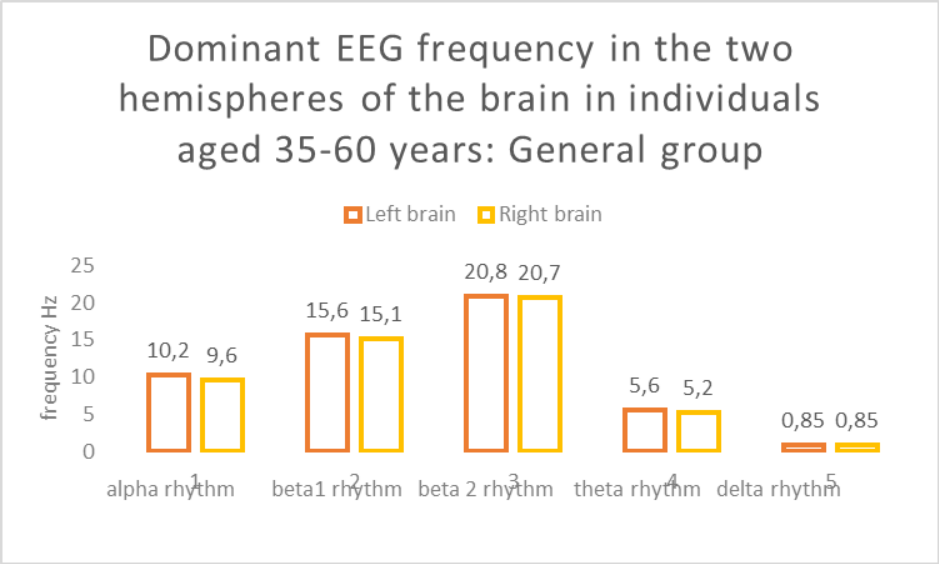

Fig. 7. General group (35-60 years): dominant frequency in two hemispheres of the brain

When examined separately in men (Table 8, Fig. 8) in the second age period of adulthood, we recorded interhemispheric asymmetry. The dominant frequency of the alpha rhythm decreased in the right hemisphere, while it increased in the theta and delta rhythms.

Table 8. Differences in the dominant frequency in the two hemispheres in men aged 35-60 years

Hemisphere	α	β1	β2	θ	σ
Left	9,5±0,20	15,7±0,28	21,3±0,47	4,6±0,16	0,6±0,07
Right	8,8±0,17*	15,4±0,26	21,0±0,44	5,9±0,18**	0,9±0,08*

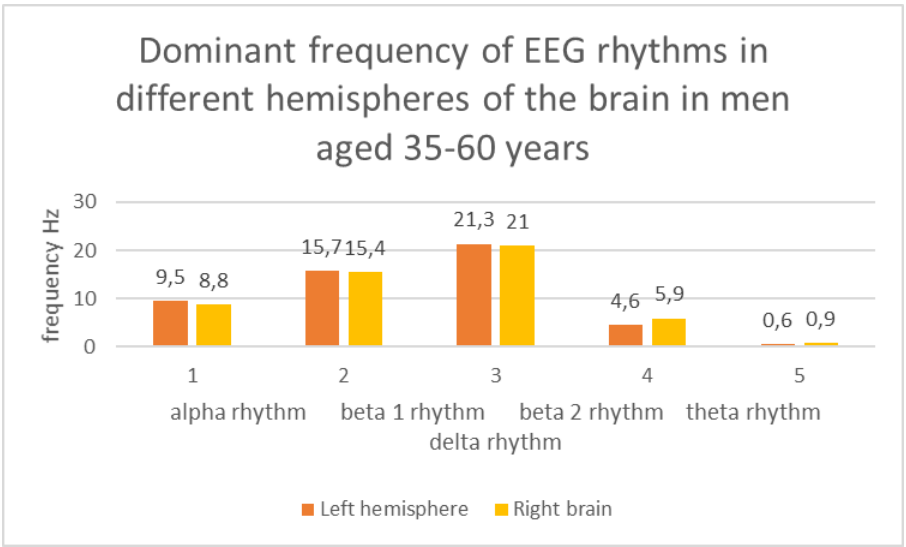

Fig. 8. Comparison of the dominant frequency in men of the second period of adulthood.

In women at this age, we recorded asymmetry in the theta rhythm (Table 9, Fig. 9). Although it is generally accepted that in females the maturation of the brain and the

specialization of the hemispheres is generally completed earlier, it is likely that some changes in electrical activity can occur at a more mature age. It is possible that this is a reflection of the intense mental activity of the women we examined. They were also university teachers. The theta rhythm is closely related to the activity of the limbic system structures and the influence of this system on the brain can apparently change during ontogenesis. Some authors attribute the theta rhythm to active participation not only in the emotional, but also in the cognitive sphere.

Table 9. Asymmetry of the dominant frequency (Hz) in the two hemispheres of the brain in women aged 35-60 years

Hemisphere	α	β1	β2	θ	σ
Left	10,8±0,19	15,5±0,33	20,3±0,43	6,5±0,19	1,1±0,10
Right	10,5±0,21	14,8±0,30	20,5±0,39	4,5±0,16**	0,9±0,09

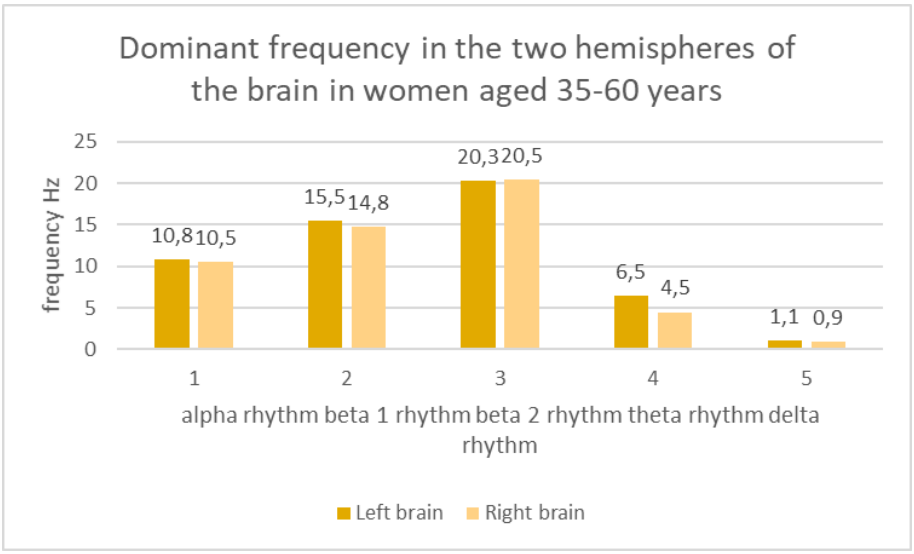

Fig. 9. Rhythm frequency in the cerebral hemispheres in women of the second period of adulthood

The figure (Fig. 10) shows the final diagram reflecting the age-related dynamics of interhemispheric asymmetry according to the dominant frequency. In general, the age-related dynamics of the dominant frequency shows that there is a tendency to decrease the value of the dominant frequency. Interhemispheric differences in the dominant frequency are observed in almost all age periods according to individual EEG rhythms.

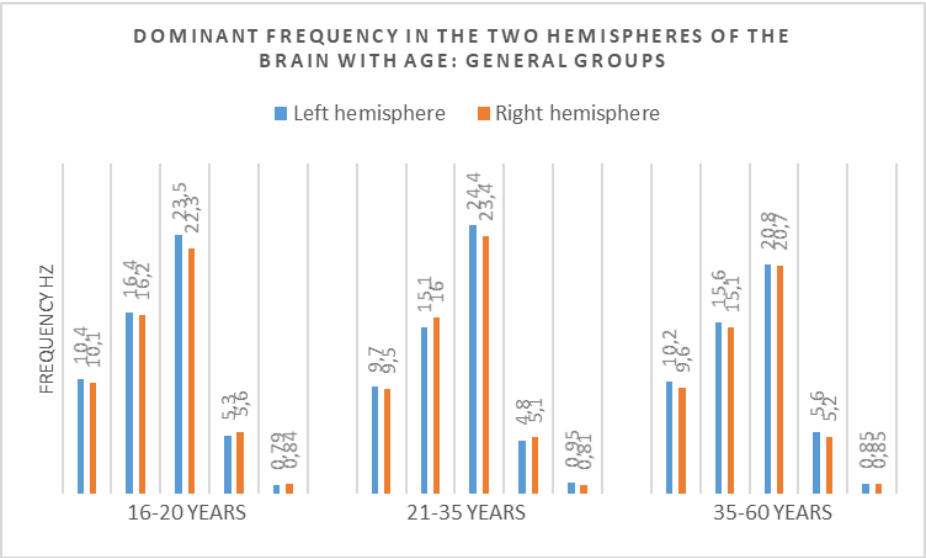

Fig. 10. Interhemispheric asymmetry of the dominant frequency of EEG rhythms in 3 periods of ontogenesis. Each age period reflects alpha, beta1, beta2, theta - delta rhythms.

In the available literature, we came across one source that describes the results of a study of asymmetry of EEG rhythms [4]. In this work, the amplitude of the alpha rhythm was studied, from which asymmetry was identified. The amplitude of the alpha rhythm was higher in the right hemisphere [4]. It is possible that there is also an asymmetry in the dominant frequency of individual EEG rhythms, which is confirmed by the results of our study.

4 Conclusions

A study of the asymmetry of the cerebral hemispheres in residents of the Czech Republic of different ages and gender indicates that, in general, the hemispheres may have slight differences in electrical activity. The dominant frequency of EEG rhythms studied in this work supports the results of some authors about the existence of electrical differences between the hemispheres. According to our data, the dominant frequency of beta and theta rhythms demonstrates asymmetry.

It should be noted that the electrical and functional maturation of the cerebral hemispheres and the brain as a whole depends on many factors. The brain, as is known, performs integrative functions in the body, controls all systems, and ensures interaction with the environment. Perhaps because of this, individual fluctuations in the bioelectrical activity of the brain are very strong, the formation of which is influenced by many factors, including active mental work.

Electrogenesis in the hemispheres also depends on which of the limbs is dominant in a person. It has been shown that in left-handed men there is greater coherence in the activity of homologous brain regions, while in right-handed men differences can be detected [6]. Our study involved only right-handed subjects.

The asymmetry of the organization of living things is one of the fundamental patterns in the organization of animals and humans. This also applies to the structural and functional organization of the hemispheres of the brain of animals and humans [4]. Our data suggest that there is an electrical difference between the hemispheres.

1. In adolescence, interhemispheric asymmetry in the dominant frequency is better expressed in girls. In young men during this period, according to our data, there was no asymmetry;

2. In adulthood - 21-35 years - asymmetry in the dominant frequency is detected in men, but was absent in women;

3. In adulthood - 35-60 years - in men the asymmetry was better expressed, since in men the asymmetry was noted in three EEG rhythms, and in women - in only one rhythm;

4. Between the ages of 16 and 60, the cerebral hemispheres show asymmetry in electrical activity.

References

1. L. K. Antropova, Functional asymmetry of the brain and individual psychophysiological characteristics of a person, **3**, 1-11 (2011)
2. S. A. Bogomaz, Bilateral model of the structure of the psyche: abstract of a dissertation for the degree of Doctor of Psychological Sciences, 46 (1999)
3. V. M. Krol, Specifics of the work of visual mechanisms of the right and left hemispheres of the human brain, **5(6)**, 1075-1084 (1995)
4. A. G. Povorinsky, Manual on clinical electroencephalography, 64 (1987)
5. N. P. Rebrova, Interhemispheric asymmetry of the human brain and mental processes, 96 (2004)
6. M. I. Tsitseroshin, *Features of the spatial organization of the EEG in left-handed children and adults. Left-handedness, anthropoisometry and lateral adaptation*, 41 (1985)
7. J. Levy, Lateral differences in the human brain in cognition and behavioral control. Cerebral correlates of conscious experience, 1 (1978)
8. J. McGlone, Sex difference in the Human Brain Asymmetry: a Critical Survey, **3(2)**, 215-263 (1980)
9. M. Pleticos, Temporal specification and bilaterally of human neocortical topographic gene expression, **81(2)**, 321-332 (2014)
10. S. F. Witelson, Sex and the single hemisphere, **193**, 425-427 (1976)
11. I. A. Butakov, The Manager, **12(3)**, 31-43 (2021)