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Comparative characteristics of bioelectric activity of the brain in long-livers from different regions of the Republic of Azerbaijan

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With application of modern technique of computerized electroencephalography comparative data of spectral-frequency analysis of baseline electroencephalography of the long-livers having high indexes of longevity and living in southern part of Azerbaijan – in Lenkoran (most of the areas are plains) and Lerik (mountainous) regions – are presented in the article. The undertaken electrophysiological studies revealed resembling and different features in the electroencephalogram (EEG) of the long-livers' populations within the different geographic areas of Azerbaijan. On the basis of comparative analysis of the recordings of baseline EEG of the long-livers of both regions one can reveal protective and inhibitory effects of the sub-cortical structures on the activity of the cortex (coming from prevalence of the indexes of delta- and theta-rhythms) accompanied with their low activities. However, in the long-livers of the Lerik region, in contrast to the long-livers of the Lenkoran region, compensatory upregulation of the activating effect of the mesencephalic reticular formation to the brain cortex was noticed. Along with the general properties of EEG, the differences in EEG patterns indicate different directions of the activation of the brain compensatory mechanisms, which gives grounds to put forward the conjecture saying that in relation to age-related changes, reorganization of neurons' communications in the central nervous system and support of high level of the brain activity in the long-livers require engagement of much more internal resources.

Keywords: *Long-livers, electroencephalogram, spectral analysis, spectral power, index, brain functional state.*

INTRODUCTION

Studies of the long-livers are one of the most actual problems of medical and biological research. The long-livers themselves present convincing illustration of physiological aging and unravelling its mechanisms presents evidences of direct relations of its processes to the changes occurring in the brain and central nervous system (CNS) (Gomazkov, 2012).

Electroencephalographic method, being used in the studies of the brain activity, its age-related changes, at present time is not just the method of analysis of the brain functional state in the clinical practice, but as well is the widely used technique for conducting research in the field of fundamental neurosciences (Kambarova et al., 2010). Bioelectric activity of the brain is closely related to the main functional states: quietness, alertness, sleep, high scale activity (Polunina, 2012). One of the main approaches of the studies of the aging-related changes is formation of a map of baseline bioelectric activity of the brain. Baseline state of electroencephalogram (closed eyes, quiet awake state) differs with its relative stable parameters (McEvoy et al., 2001) and reflects preparedness to the brain's following activity (Klimesch et al., 2006; Razoumnikova, 2003; Volf et al., 2010).

Basing on the brain-specific "language" of bioelectric activity, comparative analysis of the age-related dynamics of functional state of CNS makes it possible to determine aging rates of the brain depending on its adherence to different national-ethnic peculiarities. Particularly, according to the results of comparative electrophysiological studies conducted among the populations of Ukraine, Abkhazia and Azerbaijan (Kuznetsova,

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2008), the changes noticed in the EEG structures in Ukrainians, are more intensive than those in Abkhazians and Azerbaijanians. Meanwhile, the age-related changes of bioelectric activity in Azerbaijanians are higher relatively to Abkhazians. Having been the country characterized with high level of long-living, in several regions of Azerbaijan high level of the long-living index is observed among the local people that is termed as the group-like or population phenomenon (Kozlov, 1982). One of the zones with high long-living index is the southern zone located at the bottom of the Talysh Mountains. The main objective of the research is comparative study of the EEG structure reflecting the functional state of CNS of the long-livers living in southern zone of Azerbaijan, in Lenkoran (most of the areas are plains), and in Lerik (mountainous) possessing high levels of long-living index.

MATERIALS AND METHODS

The study comprised 36 actually healthy long-livers (at the age of over 90 years old), born and still living in Lerik (19 persons) and Lenkoran (17 persons) regions of Aerbaijan. The persons having in their disease history unconscious states, dreaming and head-brain injuries were excluded from consideration.

The EEG was fixed in 16 standard points unipolar on International System "10-20%" (Fp1/Fp2, F3/F4, C3/C4, P3/P4, O1/O2, F7/F8, T3/T4, T5/T6) with application of computer complex (Kulaichev,2007) "Neuron-Spectre-5" (Russia, 2012) under constant time 0.3 sec. The lane of filtration made 0.5-35 Hz. The frequency of digitalization made 200 Hz. Ipsilateral ear electrode was used as a reference electrode. Registration was undertaken under conditions of relaxed awakeness with closed eyes which is characterized with definite organization of EEG (Marx et al., 2004; Polunina, 2012). Computer processing of EEG was done with application of system analysis on the program of "Neuron-Spectre-Net" (Russia, 2012). Epoch of analysis made 6 sec. Each time 10 artefact-free EEG epochs, registered under baseline state, were analysed. For each outlet point with application of Fourier's quick transformation spectral power, frequency, EEG index for frequency ranges: delta (0.5-4 Hz), theta (4-7 Hz), alpha (8-13 Hz, beta-low-frequency (beta-1; 14-17 Hz), beta-high-frequency (beta-2; 20-35 Hz) were calculated.

To analysing the data the standard statistic sets of "Microsoft Excel-2007" were applied. The validity of differences in the studied groups was determined with application of the method of U-Wilkokson-Mann-Whitney criterion with defining prominence of inter-group differences. The critical level of validity was accepted as 5% ($p<0.05$).

RESULTS AND DISCUSSION

During conducting studies the brain bioelectric activity in the relatively quiet status was registered in the long-livers staying in Lenkoran and Lerik regions of Azerbaijan. Relative quietness status provides preparedness to active functioning of the brain and this is one of the important field of studies of the experimental neurophysiology (Razoumnikova, 2003; Volf et al., 2011).

On the basis of spectral analysis with computer program of EEG, being an index of the brain functional activity of the long-livers of Lenkoran and Lerik regions of Azerbaijan, comparative analysis of such basic parameters as spectral power (μV^2), index (%) and frequency range (Hz) gave an opportunity of getting novel data.

Analysis of spectral power of EEG (Fig.1) shows that in the long-livers living in both studied regions, averaged spectral power of delta-rhythm composed of low-frequency waves demonstrates dominance in the studied brain cortex areas. The highest values of delta-rhythm (25-30 μV^2) were observed in the area of Fp_1/Fp_2. Spectral power of another low-frequency rhythm – theta-rhythm – revealed dominance in the brain areas of Fp_1/Fp_2, F_3/F_4, C_3/C_4, P_3/P_4 of the long-livers of both regions.

Analysis of spectral power of high-frequency rhythms (alpha, beta 1 and beta 2) showed certain differences in the data. Averaged spectral power of alpha-rhythm in the brain parietal (P_3/P_4) and central (C_3/C_4) cortex is high (3.6-4.8 μV^2) relatively to the values of the occipital cortex (O_1/O_2) in the long-livers of both regions. However, average spectral power of alfa-rhythm in the area of C_3/C_4 of the long-livers living in Lenkoran region

is significantly higher ($p<0.05$) in compaison to the long-livers of Lerik region. Software program "Neuron-Spector.Net" presents an opportunity to analyze separately low-frequency beta 1 (14-19 Hz) and high-frequency beta 2 (20-35 Hz) rhythms of considered to be high-frequency beta rhythm. On the basis of this analysis differing results were obtained. Particularly, statistic analysis showed that averaged spectral power of beta1 rhythm in the brain cortical areas of Fp_1/Fp_2, C_4, P_3/ P_4, O_1,T_5/T_6 of the long-livers living in Lenkoran region was significant lower in comparison to the long-livers living in Lerik region ($p<0.05$). Similarly, spectral power of high-frequency beta 2 rhythm in all the studied brain cortex areas in exception of C_3 and T_3 areas in the long-livers of Lenkoran region was significantly lower relatively to the long-livers of Lerik region. High degree of statistic validity was observed in the brain frontal (Fp_1/Fp_2, F_3/F_4; $p<0.001$), parietal (P_3/P_4; $p<0.001$) and posterior temporal (T_5/T_6; $p<0.001$) cortical areas.

While conducting comparative analysis of a mean index (Fig. 2), one of the main parametric indexes of EEG, the prevalence of delta rhythm of the studied cortical areas of the brain of the long-livers, living in both regions, over the other rhythms was revealed. The mean index of this rhythm had the highest values (59-62%) in the anterior frontal (Fp_1/Fp_2) area. The mean index of theta rhythm of the studied cortical areas of the brain of the long-livers of both regions as well dominated over other rhythms and he highest values (22-24%) were noticed in the central (C_3/C_4) and parietal (P_3/P_4) areas. Statistical analysis of mean indexes of high frequency alpha, beta 1 and beta 2 rhythms of the long-livers living in Lenkoran region revealed different data relatively to the long-livers living in Lerik region. Particularly, in the long-livers of Lenkoran region in comparison to the long-livers of Lerik region mean indexes of alpha-rhythm in the left frontal (F_3), central (C_3/C_4) and left middle temporal (T_3) areas are significantly high ($p<0.05$). Conversely, mean index of beta 1-rhythm in the right parietal area (P_4), left and right frontal portion of temporal area (F_7/F_8) and left rear temporal area (T_5) of the brain of the long-livers living in Lenkoran region are significantly lower ($p<0.05$), than in the long-livers of Lerik region. This difference is as well observed in the values of mean index of beta 2 rhythm. Mean index of beta 2 rhythm of the long-livers of Lenkoran region in parietal (P_4), occipital (O_1/O_2) and temporal (F_7/F_8, T_3/T_4 and T_5/T_6) areas of the brain cortex are significantly lower, than in the long-livers of Lerik region. The highest difference ($p<0.01$) is observed in the frontal portions of temporal area (F_7/F_8).

As it issues from the results, the values of mean index of alpha rhythm significantly dominated in the certain cortical areas of the brain of the long-livers of Lenkoran region. Though low values of this index in the long-livers of Lerik region, it is accompanied with compensatory upregulation of mean index of beta rhythm.

Basing on statistical analysis of averaged frequencies, though variations of averaged frequency within range of 0.97-1.5 Hz of delta rhythm in the studied cortical areas of the brain of the long-livers living in both regions, significant differences were not revealed. However, in the long-livers of both regions averaged frequencies of delta rhythm of Fp_1/Fp_2 and O_1 areas were relatively low ($p>0.05$). The frequency of theta rhythm was high in the long-livers of Lenkoran region and made 6.15-6.63 Hz, while in the long-livers of Lerik region it made 5.76-6.28 Hz. However, these changes were not significant. The frequency of alpha rhythm in the long-livers of both regions was observed in the range of 9.33-9.68 Hz.Though the averaged frequency of beta 1 rhythm in different cortical areas in the long-livers of both regions was observed within the range of 16.07-16.64 Hz, prominent differences were not revealed. The analysis of beta 2 rhythm showed certain differences. Basing on the analysis of averaged frequency of beta 2 rhythm in the frontal (Fp_1, F_3), parietal (P_3) and temporal (F_7, T_3) areas of the brain cortex, significant ($p<0.05$) downregulation of its level was noticed.

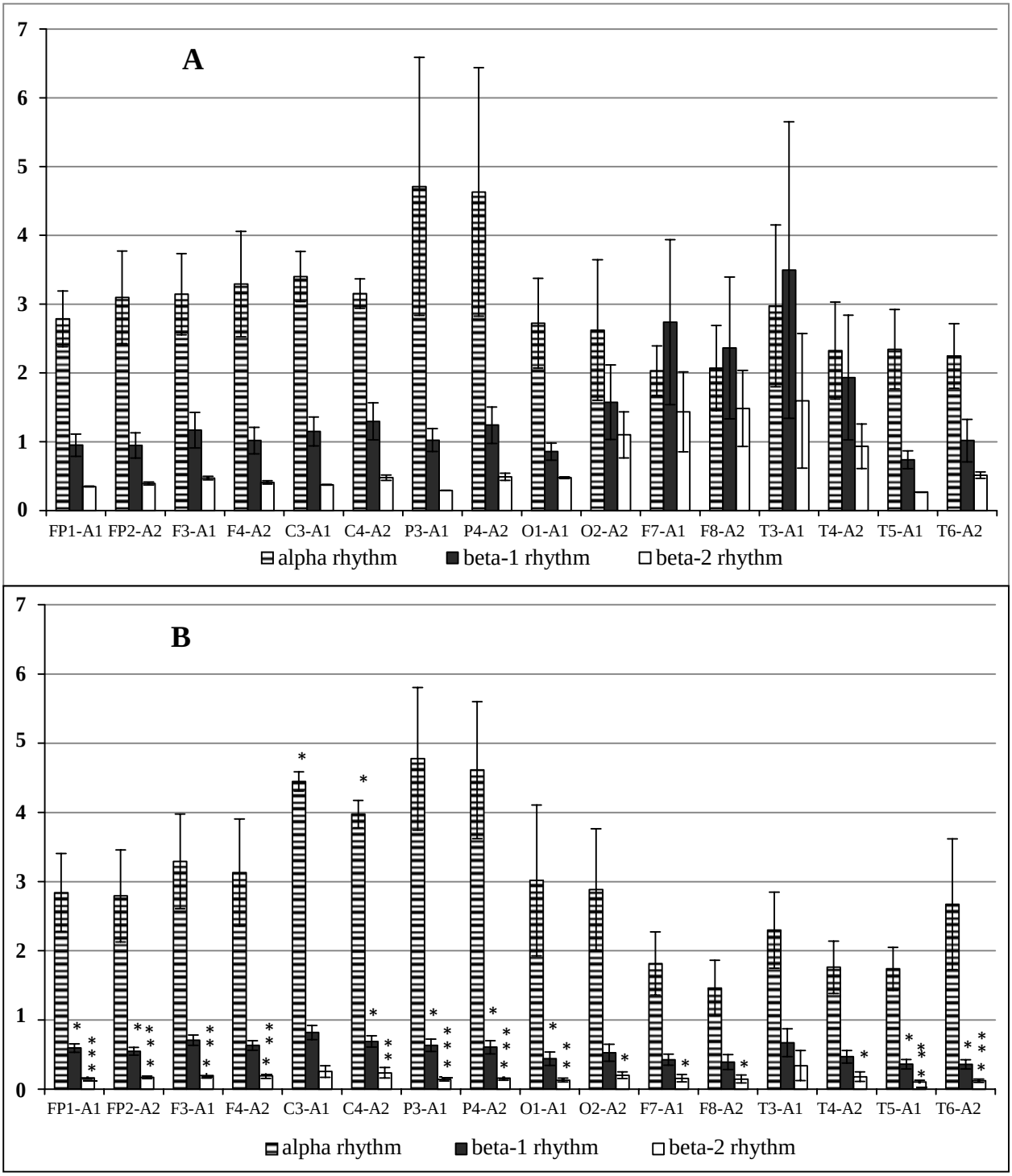

Fig. 1. Background EEG power spectrum from Lerik (A) and Lankaran (B) long-livers.
The horizontal axis represents the labeles of 16 channels, the vertical axis shows power spectrum density (μV^2). * - $p<0.05$, **$p< 0.01$, ***$p< 0.001$

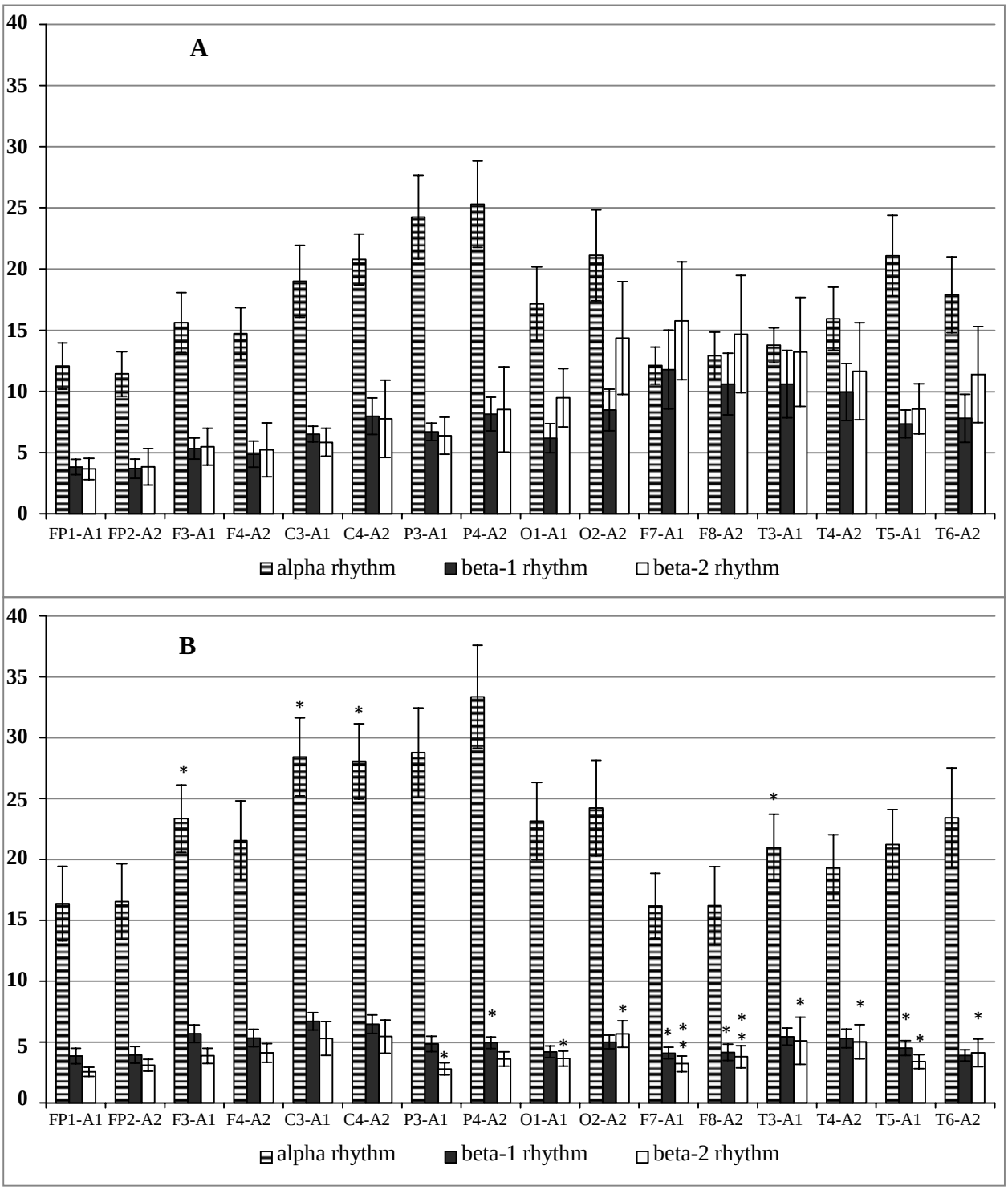

Fig.2. Background EEG rhythm indexes in Lerik (A) and Lankaran (B) long-livers. The horizontal axis shows acronyms of 16 channels, the vertical axis displays rhythms indexes (%). * - $p<0.05$, **$p< 0.01$

As it is seen from the results, EEG analysis of the long-livers, living in Lenkoran and Lerik regions, revealed both similar and distinct features. EEG, being an epoch of neuronal constellations, reflects their changing activity. Due to spectral power of EEG, one can put forward an idea of composition of this epoch. The results of spectral analysis of EEG showed dominance of spectral power and index of slow rhythms (delta and theta rhythms) over other rhythms of the long-livers living in Lenkoran and Lerik regions. In the most of publications concerning age-related changes of slow rhythms (delta and theta rhythms), upregulation of their power, while in the least of cases age-related changes (Blalock et al., 2003; Carlson et al., 2004; Van Cott, 2002) were observed during aging. In total spectral power of EEG, upregulation of relative part of delta rhythm is related to downregulation of the brain functional activity (Deryabina, 2016), while downregulation of frequency of the frontal and occipital cortical areas of the brain relatively to the other areas of the brain cortex is related to downregulation of activating effects of the sub-cortical system which defines the frequency characteristics of slow waves (Moretti et al., 2012). In the publication concerning studies of peculiarities of regional distribution of alpha rhythm (Volf et al., 2011), one of the high frequency rhythms (alpha, beta 1 and beta 2), decline of power of alpha rhythm towards rear portions of brain hemispheres in baseline EEG of the long-livers is explained in terms of more effective functionalization of the brain structures. It is known that rear portions of the brain are engaged in storage of short-term memory and analysis of vision-surrounding images (Klimesch et al., 2006). There are evidences in the literature concerning age-related stability and decline (Liddell et al., 2007) of beta activity. However, the most of publications notice upregulation of high frequency activity (beta rhythm) during normal aging (Volf et al., 2011; Vysata et al., 2012; Zenkov, 2010). There are publications showing positive correlation between upregulation of high frequency waves (beta rhythm) and effectivity of cognitive functions during aging (Volf et al., 2011). Downregulation of power of beta rhythm in the people having primary manifestations of dementia and in the people with psychic impairments (Liddell et al., 2007) supports this idea. The results of our studies showed that in the long-livers living in Lerik region in comparison to the long-livers of Lenkoran region on the background of downregulation of alpha rhythm, compensatory upregulation of spectral power and index of beta rhythm indicates to decline of the activity of thalamo-cortical synchronizational system and prevailing of the activating effects of the mesencephalic reticular formation onto the brain cortex (Gordeev, 2007; Zenkov, 2010). During aging effectivity of brain activity is defined by 2 processes: the level of age-related brain degradation and launching of the compensatory mechanisms (Volf et al., 2011). It should be noted that brain responds to age-related changes through "compensatory support". Studies conducted on the animals, show that adaptation potential of the brain to the age-related changes occurs on account of neurogenesis and changes of synaptic plasticity. These processes are realized through proliferation and differentiation of precursor cells and thereafter redistribution of these nervous cells within the brain structures (Kempermann et al., 2002). The results obtained from the long-livers living in Lerik region showing prevalence of beta activity in frontal and temporal cortical areas of the brain during aging are consistent with the idea of the physiological changes of EEG and upregulation of compensatory activities in these structures.

So, the results of the conducted electrophysiological studies indicate to various changes in EEG and to mobilization of compensatory mechanisms of the brain in different directions in the long-livers, living in different geographic regions of Azerbaijan. Along with age-related development of the involutional changes, these data reflect launching the adaptive-compensatory processes.

CONCLUSIONS

1. Prevalence of indexes of slow rhythms (delta and theta rhythms) in the baseline EEG of the long-livers living in Lenkoran and Lerik regions, indicates to development of protective inhibition and low functional activity of the brain which are related to strengthening of the synchronizing effects of the thalamo-cortical system and decline of the activating effects of the sub-cortical system.

2. Comparative analysis of baseline EEG of the long-livers showed that in the long-livers living in Lerik region, in contrast to the long-livers of Lenkoran region, on the background of decline of alpha rhythm, compensatory upregulation of the spectral power and spectral index of beta rhythm indicates to compensatory strengthening of the activating effects of the mesencephalic reticular formation on the brain cortex.

3. The obtained results of electrophysiological studies show that along with general features, presence of differences in EEG of the long-livers, living in different long-livers populations in different geographic regions of Azerbaijan, indicates to launching of the compensatory mechanisms of the brain in different directions. This give grounds to putting forward an idea that reorganization of the neuronal networks of the central nervous system and supporting active functioning of the brain of the long-livers, subjected to age-related physiological changes, require engagement of much more internal resources.

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Azərbaycanın müxtəlif rayonlarında yaşayan uzunömürlülərdə baş beynin bioelektrik fəallığının müqayisəli xarakteristikası

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Məqalədə müasir kompüter elektroensefaloqrafiyası metodundan istifadə etməklə Azərbaycanın cənub zonasının uzunömürlülük indeksi yüksək olan Lənkəran (ərazisi əsasən düzənlik) və Lerik (dağlıq) rayonlarında yaşayan uzunömürlülərdə fon elektroensefaloqrammanın spektral-tezlik analizinin müqayisəli nəticələri verilmişdir. Aparılmış elektofizioloji tədqiqat işi Azərbaycanın müxtəlif coğrafi ərazilərindəki uzunömürlü populyasiyalarında uzunömürlülərin elektroensefaloqrammasında (EEQ) oxşar və fərqli xüsusiyyətlərin olduğunu göstərir. Uzunömürlülərin fon EEQ-nin müqayisəli analizi əsasında hər iki rayon uzunömürlülərində baş beynin funksional vəziyyətinin qabıqaltı strukturların qabığın fəallığına tormozlayıcı (delta- və teta-ritmlərin göstəricilərinin dominantlığı zəminində) təsiri ilə müşayiət olunan aşağı fəallıqla xarakterizə edildiyi, ancaq Lerik rayonunda yaşayan uzunömürlülərdə Lənkəran uzunömürlülərindən fərqli olaraq mezensefal retikulyar formasiyanın baş-beyin qabığına aktivləşdirici təsirinin kompensator yüksəlməsi müəyyənləşdirilmişdir. Uzunömürlülərin EEQ-də ümumi cəhətlərlə yanaşı fərqliliyin olması beynin kompensator mexanizmlərinin fəallaşmasının müxtəlif istiqamətini göstərir ki, bu da uzunömürlülərdə fizioloji yaş dəyişikliyinə məruz qalan mərkəzi sinir sisteminin neyron şəbəkəsinin yenidən təşkili və beynin aktiv fəaliyyətini təmin etmək üçün daha çox resursun işə cəlb edilməsi haqqındakı fərziyyəni irəli sürməyə imkan verir.

Açar sözlər: *Uzunömürlülər, elektroensefaloqramma, spektral analiz, spektral güc, indeks, baş beynin funksional vəziyyəti*

Сравнительная характеристика биоэлектрической активности головного мозга у долгожителей, проживающих в различных районах Азербайджана

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В статье представлены сравнительные результаты спектрально-частотного анализа фоновых электроэнцефалограмм, полученных методом современной компьютерной электроэнцефалографии у долгожителей Ленкоранского (в основном равнинного) и Лерикского (горного) районов южной зоны Азербайджана, характеризующихся высоким индексом долголетия. Электрофизиологическое исследование показало схожие и отличительные особенности в ЭЭГ коры мозга у долгожителей в популяциях различных географических районов Азербайджана. Сравнительный анализ фонового ЭЭГ у долгожителей обоих районов выявил низкую активность функционального состояния головного мозга, сопровождающуюся тормозящим влиянием подкорковых структур на активность коры. Тем не менее, показано, что по сравнению с долгожителями Ленкоранского района, в ЭЭГ мозга долгожителей Лерикского района преобладает активирующее влияние мезенцефальной ретикулярной формации на кору головного мозга, что можно объяснить различием уровня активности компенсаторных механизмов мозга у изучаемых долгожителей обоих районов. Предполагается, что полученные физиологические изменения в ЭЭГ мозга могут быть связаны с реорганизацией нейронной сети с привлечением больших ресурсов для обеспечения активной деятельности мозга.

Ключевые слова: *Долгожители, электроэнцефалограмма, спектральный анализ, спектральная мощность, индекс, функциональное состояние мозга*