ISSN 2304-3415, Russian Open Medical Journal
2023. Volume 12. Issue 4 (December). Article CID e0407
DOI: 10.15275/rusomj.2023.0407

Original article

Changes in objective characteristics in brain electrical activity in newborns as a function of birth weight

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Received 20 June 2023, Revised 11 September 2023, Accepted 18 October 2023

Abstract: The *aim* of the present study was to detect characteristic features of oscillatory electrical activity of the brain in the first day of postnatal life depending on the weight of newborns.
Material — Eighteen neonates of conditionally normal gestational age (37.7±1.5 weeks) weighing 2500±720 g were included in the study. All neonates were children of first births of mothers aged 18-35 years, all pregnancies were physiologic, conventionally normal, without significant complications. The height of the newborns was 47±4.643 cm and head circumference was33.0±2.908 cm. The Apgar score at delivery was 7-9 points. All newborns were divided among groups 1 (weight: 2850-4000 gr), 2 (weight: 2000-2800 gr) and 3 (1200-2000 gr). Each newborn underwent EEG monitoring (EEG, monopolar recording, channels C3 and C4) for 40 minutes during the first 12 hours after birth.
Methods — Automatic processing of EEG was performed without separating the monitoring records into sleep and wakefulness stages. Oscillatory patterns were calculated for each EEG channel based on the continuous wavelet transform method. Statistical estimations of the number and duration of oscillatory patterns developing in different EEG frequency ranges were performed.
Results — A strong correlation was found between neonatal birth weight and integral characteristics of the number \ duration of oscillatory patterns in the low-frequency band [4; 6] Hz (r=-0.878\0.920). Practically healthy newborns with different birth weights show statistically different EEG characteristics in the [4; 6] Hz band in the first 12 hours after birth (p-value≤0.005).
Conclusion — Electrical activity of the brain varies significantly depending on the weight of newborns immediately after birth. Monitoring of EEG signals according to the proposed algorithm may become the basis for the development of additional tools for early detection of possible disorders of neurological development of the newborn.

Keywords: brain activity, newborns, neonatal EEG, continuous wavelet analysis, oscillatory patterns.

Cite as Runnova AE, Zhuravleva YuA, Egorov EN, Drozhdeva EE. Changes in objective characteristics in brain electrical activity in newborns as a function of birth weight. *Russian Open Medical Journal* 2023; 12: e0407.

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Introduction

The research presented in our paper is aimed at studying the brain development of newborns at the very beginning of postnatal life. At this time, the infant brain undergoes dramatic changes that are quite difficult to study objectively in vivo. Despite the considerable fundamental interest in brain development in the early postnatal period, the study also has clear applied goals. Objective criteria of norms and abnormalities in the condition of the newborn can help early help and rehabilitation of the child even before the development of neurological disorders. For today's developed society, the challenges of increasing average parental age and the number of preterm births, resulting in a higher proportion of low-birth-weight babies, lead to a significant interest in objective decision support tools for clinical professionals, both to monitor the care of low-birth-weight babies and to reduce the risks of neurologic impairment and early detection of possible cognitive impairment. Despite all the advances in clinical neonatology, the number of children demonstrating neurologic impairment is increasing. For example, the Center for Disease Control (USA) reports that the incidence of autism spectrum disorders has increased from 1 case per 166 8-year-old children in 2004 to 1:36 in 2023 [1]. Correct non-invasive methods of early assessment of neurophysiologic state of the brain of newborns could be useful to study the possibility of creating prognostic criteria for autism spectrum disorders, speech disorders, intellectual disability and others.

Today, in the clinical practice of working with newborns, EEG analysis is often based on the amplitude-integrated EEG (aEEG) method, which is based on a compressed one-dimensional representation of long-term recordings of two or more EEG channels together and allows, based on the identification of typical trends, a quick and relatively objective conclusion about the current state of cerebral function and an assessment of its dynamics. In addition, aEEG is used to develop fully automated methods of child monitoring, for example, in the assessment of brain maturation [2, 3] and the classification of sleep states [4, 5].

At the same time, the use of aEEG is obviously a significant simplification of the processes of brain activity, reducing the entire complex multi-frequency distributed oscillatory dynamics of electrical potentials to an average characteristic obtained from spatially distributed electrode points. Thus, although characteristic trends of AEEG have been successfully identified for critical and convulsive states of premature infants, the markers of normal or slightly pathologic processes of development of brain electrical activity in the immediate period after birth in preterm and slightly premature low birth weight infants remain poorly studied.

Previously, in *Kiselev, et al* (2022), *Zhuravlev, et al* (2023) [6, 7], the team evaluated the occurrence and dynamics during the first weeks of life of electrophysiological markers of deep (quiet) and active sleep, as well as wakefulness of newborns of different gestational ages in terms of classical frequency-time analysis based on continuous wavelet transform (CWT). In this paper, we aim to study the characteristics of the electrical activity of the brain of premature newborns with conditionally normal gestational age and their relationship with birth weight. The study included 18 conditionally healthy newborns with different birth weights. The study of the number, duration and energy of CWT oscillatory patterns allows us to observe a pronounced correlation between the characteristics of neonatal brain activity and birth weight. Further study of the capabilities of the proposed method and its validation in longitudinal studies seems promising for the creation of automatic systems to support medical decisions for the early detection of damage to the development of the central nervous system of newborns.

Material and Methods

The first part of this section provides the necessary information about clinical studies in which procedures for recording electrical activity of the brain were carried out. Our research was carried out in accordance with the requirements of Declaration of Helsinki [8] and were approved by the Ethics Committee at State Medical University of Saratov, Ministry of Healthcare of the Russian Federation. All experiments were performed in accordance with relevant guidelines and regulations. Before the onset of the study, written informed consent for monitoring, subsequent mathematical processing of the data, and publication of the results was obtained from all parents (or legal guardians of participants). Parents were present during all experiments in compliance with the requirements of the Russian Federation legislation.

In the second part, all methods used for EEG processing are described. The use of these methods is aimed at searching for and quantifying differences in the oscillatory structure of the electrical activity of the brain in the first six hours after birth.

Clinical materials

The experimental material was collected during a clinical study, which included 18 newborns.

The inclusion criteria for the study were: gestational age at birth over 35 weeks, Apgar score over 7, and voluntary informed consent signed by the parents of a newborn child. To improve the statistical significance of intergroup differences and to reduce an impact of lurking variables, solely naturally born children (i.e., without any surgical interventions) were included in our study. The exclusion criteria were as follows: grade 3 intraventricular hemorrhage with a breakthrough into the brain substance, presence of a genetic pathology, and gross congenital malformations. All newborns underwent a complete clinical examination in accordance with the neonatology standards for the provision of medical care.

All newborns were divided among groups 1 (weight: 2850-4000 gr), 2 (weight: 2000-2800 gr) and 3 (1200-2000 gr). *Table 1* presents a brief description of the results of examination of newborns by a neonatologist, as well as statistical characteristics of the all-patient data, and for each group.

Each child underwent a noninvasive and painless functional monitoring procedure at 8 h after the birth. The duration D of monitoring session was about D=40-45 min. During the monitoring, each child was located in the crib. Monitoring of newborns was carried out at the clinical departments for newborns within the framework of scientific and clinical cooperation with SSMU. The data of 2-channel noninvasive monitoring of biomedical EEG signals were recorded using the Encephalan-EEGR-19/26 electroencephalograph (Medicom MTD LLC, Russia). All signals were sampled at 512 Hz and digitized at 16 bits for offline analysis using a personal computer. EEGs were obtaned via conventional monopolar recording method with two reference points and C3 and C4 electrodes arranged according to the 10–20 layout [9]. Signals were recorded using Ag/AgCl electrodes in pre-mounted head units. Two reference electrodes, A1 and A2, were located on the mastoid processes, while the ground electrode N was placed above the forehead. The EEG signals were filtered by a band pass filter with cutoff points of 0.5 Hz and 40 Hz, and a notch filter of 50 Hz.

During the monitoring, the following behavioral activities were recorded among the newborns: sleep (5), drowsiness (10), quiet wakefulness (10), wakefulness with single movements (5), wakefulness with vocalization (3), and transitions between wakefulness and sleep states (18). Further processing was performed on the entire electroencephalography recording without singling out specific behavioral states.

EEG data processing

To study the frequency-time characteristics of electroencephalography, the classical continuous wavelet transform (CWT) was used to estimate the power dynamics of oscillatory activity in different frequency intervals with good temporal resolution [10]. The continuous wavelet transform $W_i(f, t)$ was calculated for each EEG signal x_i based on the Morlet mother wavelet with the parameter $\Omega_0=2\pi$:

$$W_i(f,t)=\sqrt{f}\int_{t-4/f}^{t+4/f} x_i(t)\left(\sqrt{f}\pi^{1/4}e^{j\omega_0 f(t-t_0)}e^{\frac{f(t-t_0)^2}{2}}\right)^{*}dt, \qquad (1)$$

where "*" – complex conjugation procedure.

Using this value of the parameter Ω_0, the time scales of the CWT can be represented in the classical frequencies of the Fourier spectrum f, Hz. The following processing algorithm was used to analyze the oscillatory activity on the EEG.

1). For each EEG channel, the energy power $E(f, t)$ in band [1.0; 20] Hz was calculated according to:

$$E(f,t) = |W_i(f,t)|^2. \qquad (2)$$

Table 1. Physical characteristics of newborns and statistical estimation

#	Group	Sex	Gestational age, weeks	Weight, gr	Height, cm	Head circumference, cm
1	1	M	40.6	4000	53	38
2	1	M	39.0	3550	52	36
3	1	M	39.5	3250	51	36
4	1	M	40.4	3100	51	35
5	1	M	37.5	3000	50	36
6	1	F	38.5	2880	46	34
7	2	M	38.0	2800	52	36
8	2	M	37.0	2650	45	33
9	2	M	37.1	2630	48	35
10	2	M	36.4	2450	49	33
11	2	M	35.0	2323	48	33
12	2	M	38.5	2280	46	32
13	3	M	36.5	1970	46	30
14	3	M	36.3	1930	46	32
15	3	F	37.0	1920	37	30
16	3	M	37.9	1900	44	30
17	3	F	38.0	1500	41	30
18	3	M	36.6	1220	38	27
STATISTICAL DESCRIPTION:						
All newborn						
Mean			37.8	2519.6	46.8	33.1
Median			37.7	2540.0	47.0	33.0
Standard deviation			1.5	720.1	4.7	2.9
Group # 1						
Mean			39.2	3296.7	50.5	35.8
Median			39.3	3175.0	51.0	36.0
Standard deviation			1.2	415.1	2.4	1.3
Group # 2						
Mean			37.0	2522.2	48.0	33.7
Median			37.1	2540.0	48.0	33.0
Standard deviation			1.2	204.3	2.5	1.5
Group # 3						
Mean			37.0	1740.0	42.0	29.8
Median			36.8	1910.0	42.5	30.0
Standard deviation			0.7	308.2	3.9	1.6

M, male; F, female.

The method of oscillatory patterns estimation is based on a special sorting of local extrema, i. e., skeletons.

2). At each time instant t_0, a set of frequencies f_j, where j=1, 2, ..., m, corresponding to a local maximum $E(f_j, t_0)$ (2) is compiled. Here, the ordinal number j characterizes only the ordinal number of extrema and is not related in any way to the amplitude of the value $E(f_j, t_0)$ (2). Thus, in the process of analyzing the full duration of the investigated signal, a set of frequencies f_j^n is formed, where n is the duration of the experimental signal, i. e., the number of time samples in the record.

3). The condition of oscillatory activity pattern development is introduced into consideration. For this purpose, at each time interval $[t_i; t_{i+1}]$ for each frequency f_j the following condition must be fulfilled:

$$|f_j^i + f_j^{i+1}| < \delta, \quad (3)$$

where f_j^i — is the set of frequencies for which the local maximum $E(f, t)$ (2) is observed at time step t_i, and f_j^{i+1} is the similar set of frequencies with the local maximum $E(f, (t+\Delta t))$ (2) for the next time step t_{i+1}, and δ is a numerical constant. The choice of the δ - constant value is based on the sampling frequency of the analyzed signal and should exceed Δt by 1-2 orders of magnitude, which allows to minimize the loss of information about frequency patterns existing in the studied signal, as well as to reduce the influence of numerical noise of the signal.

4). Condition (3) is checked for the extreme frequency at each time instant. If condition (3) is satisfied for the frequencies f_{a1}^i and f_{a2}^{i+1}, then the activity at these frequencies during the time interval $[t_i, t_{i+1}]$ will be considered as the development of a single oscillatory pattern. For simplicity of interpretation, we denote the values of frequencies f_{a1}^i and f_{a2}^{i+1} as (Φ1) and (Φ2), respectively. For frequency (Φ2), we again check the fulfillment of condition (3) for the next time step t_{i+2}. If the condition is also satisfied for this time step, the identified oscillatory pattern will continue further with a certain frequency (Φ 3).

5). The described actions should be cyclically repeated until the moment when condition (3) becomes incorrect, which will mean the end of the activity of this oscillatory pattern. Thus, each oscillatory pattern P can be described by a precisely defined frequency at each moment of time of its existence, i. e.:

$$P(f,t) = \{((\Phi 1), t_i), ((\Phi 2), t_{i+1}), \dots, ((\Phi m), t_{i+m})\}, \quad (4)$$

where parameter m characterizes the time of "life" or existence of an oscillatory pattern P. Then the duration T of an individual pattern P can be defined as

$$T = t_{i+m} - t_i, \quad (5)$$

In the case of equidistant experimental time series, the expression T=$m\cdot\Delta t$, where Δt is the sampling time interval. Thus, the average frequency Φ_{md} can be estimated for each frequency pattern P as follows:

$$\Phi_{md} = \sum_{i=1}^{m} \frac{\Phi_i}{m}, \quad (6)$$

6). The duration T and the average frequency Φ_{md} of each pattern are independent values, which allows us to introduce an additional criterion for selecting correct oscillatory patterns P. Let the duration T of an oscillatory pattern P not exceed the period of oscillations of its average frequency Φ_{md}:

$$T < \frac{1}{\Phi_{md}}. \quad (7)$$

In this case, the pattern P should be considered as a random noise interference and not taken into account in further signal analysis. This method was proposed and tested earlier [11-14]. Each detected pattern P is characterized by two characteristics: average frequency, Φ_{md}, and duration, T.

7). To proceed to the description of the statistical characteristics of oscillatory patterns, we consider a set of bands: Δf_1 [1, 2], Δf_2 [2, 4], Δf_3 [4, 6], Δf_4 [6, 8], Δf_5 [8, 10], Δf_6 [10, 12], Δf_7 [12, 14], Δf_8 [14, 16], Δf_9 [16, 18], Δf_{10} [18, 20] Hz. Within each frequency interval Δf at each time instant t, the number N of patterns whose mean frequency Φ_{md} belongs to this interval, $\Phi_{md} \in \Delta f$, was calculated.

8). Then, the number of patterns N_Δ was averaged over the entire signal realization for time windows of duration Δt=5 s in each frequency range. In addition, the average duration of the patterns, T_Δ, was estimated for the same time windows in a similar manner. Thus, each time interval Δt of the EEG signal was described by 20 numerical characteristics, namely N_Δ, T_Δ for each frequency range Δf_1-Δf_{10}.

9). The whole duration of the EEG signal can be described by averaged characteristics <N>, <T>:

$$\langle N \rangle = \sum_{i=1}^{D/\Delta t} \frac{N_\Delta|_i}{D} \cdot \Delta t, \quad \langle T \rangle = \sum_{i=1}^{D/\Delta t} \frac{T_\Delta|_i}{D} \cdot \Delta t, \qquad (8)$$

estimated in each band $\Delta f_1 - \Delta f_{10}$.

10). Additionally, for integral estimation of brain electrical activity in sensorimotor projection, the total response for two registered symmetric EEG channels was calculated:

$$^{C3}_{C4}\langle N \rangle = \frac{\Delta t}{2 \cdot D} \cdot \sum_{i=1}^{D/\Delta t} [(N_\Delta|_i)^{C3} + (N_\Delta|_i)^{C4}], \quad ^{C3}_{C4}\langle T \rangle = \frac{\Delta t}{2 \cdot D} \cdot \sum_{i=1}^{D/\Delta t} [(T_\Delta|_i)^{C3} + (T_\Delta|_i)^{C4}]. \qquad (9)$$

Statistical data processing

Mean, median, and standard deviation were used in descriptive statistics of collected data. The Mann-Whitney U test for independent samples was performed for the comparison of quantitative data. Calculation and graphing of distributions of N and T coefficients made in OriginLab version 6.1. The results with a p-value≤0.05 were assumed statistically significant. Statistical analyses were conducted by SPSS version 22.0 software for Windows (IBM, Armonk, NY, USA).

Results

The estimated number <N> and duration <T> of oscillatory patterns P for EEG channels C3 and C4 in each frequency band Δf_1 - Δf_{10} are given in Tables 2 and 3, respectively. Standard statistical analysis of these characteristics for oscillatory patterns in the three groups of newborns showed that the maximum differences between brain electrical activity in newborns with different birth weights were observed in the frequency range Δf_3 [4, 6] Hz, as shown in Figure 1.

The differences in the number <N> and duration <T> of oscillatory patterns P evaluated summarily in the two recorded EEG channels are statistically significant. Thus, each group of newborns is characterized by its own values of the average number and the duration of oscillatory patterns in the frequency band Δf_3.

In addition, for a given band Δf_3 integral characteristics $^{C3}_{C4}\langle N \rangle$ and $^{C3}_{C4}\langle T \rangle$ (7) of patterns, calculated from the two channels of the electroencephalogram C3 and C4, show a clear correlation with the weight of newborns. The corresponding correlation fields are shown in Figure 2; the correlation coefficients between weight and the integral number of $^{C3}_{C4}\langle N \rangle$ patterns and between weight and the integral duration of $^{C3}_{C4}\langle T \rangle$ patterns are $r_{w\backslash N}$=-0.878 and $r_{w\backslash T}$=0.920.

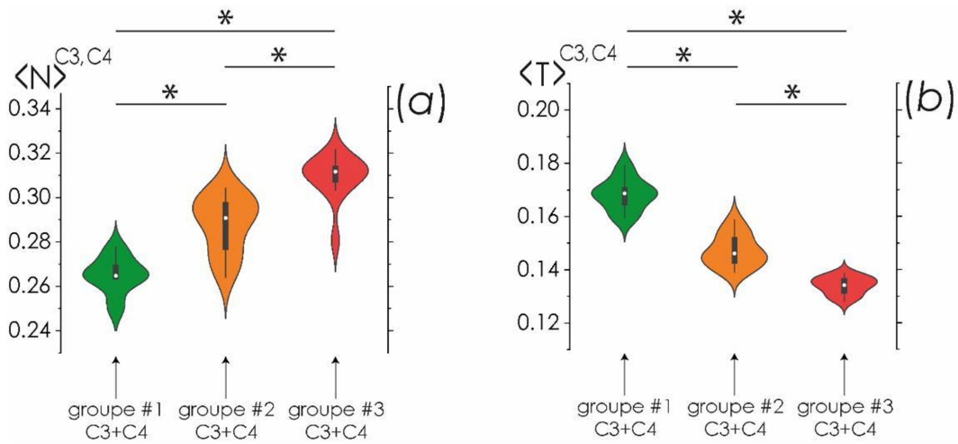

Figure 1. Diagrams of the mean number of <N>$^{C3, C4}$ and <T>$^{C3, C4}$ (8) for in-band Δf_3 oscillatory patterns in EEG channels C3 and C4 estimated from signals recorded in three groups of neonates, respectively.

The white dot in the diagrams corresponds to the median of the data. The width of the diagrams corresponds to the probability distribution of values. Asterisks indicate significant differences between experiments according to the Mann-Whitney U test (p-value≤0.005).

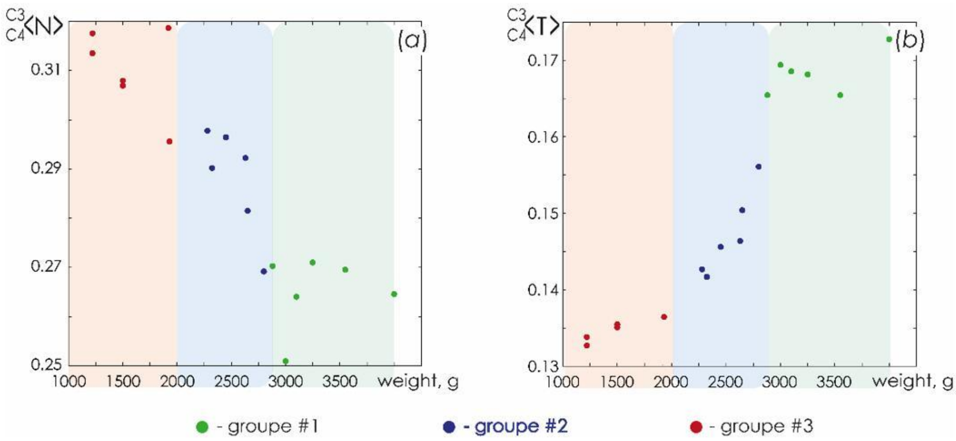

Figure 2. Correlation fields of integral characteristics $^{C3}_{C4}\langle N\rangle$ and $^{C3}_{C4}\langle T\rangle$ (9) and neonatal weight. The following color codes are used in the figure: green, blue and red colors show the results of the EEG assessment for participants in group #I, #II and #III, respectively.

$^{C3}_{C4}\langle N\rangle$ and $^{C3}_{C4}\langle T\rangle$ (7) were evaluated for oscillatory patterns in the frequency range Δf_3. The total number of points in each figure is the same as the number of newborns.

Table 2. Estimations of the mean number of oscillatory patterns for EEG channels C3 and C4 over the entire monitoring period

№	Channel	Δf_1	Δf_2	Δf_3	Δf_4	Δf_5	Δf_6	Δf_7	Δf_8	Δf_9	Δf_{10}
1	C3	0.144277	0.342596	0.252892	0.273941	0.30786	0.305136	0.314807	0.343277	0.336194	0.356627
	C4	0.172339	0.327737	0.277559	0.279962	0.305214	0.293202	0.31941	0.327054	0.326918	0.312312
2	C3	0.131251	0.316042	0.262922	0.27539	0.301259	0.291678	0.313304	0.358199	0.342869	0.353408
	C4	0.128252	0.332339	0.264098	0.287322	0.303593	0.311864	0.334373	0.393492	0.397424	0.408136
3	C3	0.140621	0.322084	0.274238	0.278618	0.324649	0.3152	0.384989	0.531857	0.557775	0.610016
	C4	0.163856	0.328083	0.292222	0.276616	0.306898	0.306491	0.342205	0.41214	0.433596	0.451793
4	C3	0.154156	0.314446	0.270781	0.276718	0.291124	0.296337	0.324873	0.394018	0.374949	0.390177
	C4	0.167712	0.323437	0.289337	0.278905	0.315675	0.295792	0.363475	0.437423	0.435108	0.443143
5	C3	0.161946	0.289736	0.295162	0.278779	0.283634	0.272954	0.29362	0.341331	0.359223	0.356449
	C4	0.159724	0.319586	0.288612	0.308561	0.340547	0.328842	0.347353	0.394583	0.402477	0.401116
6	C3	0.141344	0.301831	0.304277	0.267119	0.287186	0.291254	0.307254	0.384	0.390237	0.397288
	C4	0.172693	0.272027	0.301403	0.244992	0.267965	0.260261	0.270766	0.317411	0.297381	0.290937
7	C3	0.1523	0.282379	0.278987	0.257067	0.27127	0.258895	0.274364	0.283645	0.268176	0.258051
	C4	0.152859	0.294699	0.297071	0.261192	0.267646	0.280143	0.303351	0.318182	0.329854	0.34345
8	C3	0.159956	0.324177	0.298485	0.289094	0.309763	0.276176	0.301741	0.340223	0.327169	0.343351
	C4	0.169311	0.29886	0.310516	0.273283	0.285933	0.26119	0.270364	0.292883	0.288018	0.277314
9	C3	0.136091	0.335288	0.28068	0.28661	0.307745	0.291655	0.326561	0.437415	0.448596	0.488819
	C4	0.158464	0.329584	0.315711	0.293942	0.313593	0.306546	0.342594	0.425261	0.44586	0.47852
10	C3	0.166622	0.330133	0.321622	0.312821	0.327833	0.326751	0.386935	0.485664	0.511902	0.562213
	C4	0.175179	0.329803	0.303463	0.328988	0.361711	0.345553	0.363747	0.410998	0.426341	0.494773
11	C3	0.15243	0.339854	0.31041	0.309228	0.29776	0.324744	0.408527	0.627766	0.724906	0.821236
	C4	0.175202	0.320297	0.303504	0.274442	0.265216	0.259708	0.290278	0.38667	0.43762	0.488158
12	C3	0.15243	0.32106	0.31041	0.23417	0.22622	0.274477	0.346862	0.419386	0.419526	0.433194
	C4	0.162414	0.321277	0.312947	0.268732	0.272963	0.285519	0.346936	0.40999	0.428279	0.43988
13	C3	0.166419	0.33553	0.314212	0.321006	0.323292	0.313609	0.355971	0.408822	0.417025	0.437735
	C4	0.162392	0.301992	0.312905	0.284441	0.279426	0.268004	0.28263	0.317872	0.319961	0.330408
14	C3	0.166397	0.335181	0.31417	0.326798	0.348432	0.346539	0.389129	0.480665	0.490535	0.549351
	C4	0.144277	0.339054	0.252892	0.342432	0.374459	0.358108	0.407838	0.484595	0.515811	0.557297
15	C3	0.172339	0.31613	0.277559	0.316534	0.314109	0.304406	0.348201	0.42757	0.437542	0.457351
	C4	0.131251	0.32476	0.262922	0.325843	0.327873	0.324354	0.386896	0.518343	0.534859	0.596047
16	C3	0.128252	0.316173	0.264098	0.316577	0.314151	0.304447	0.348248	0.427628	0.437601	0.457412
	C4	0.140621	0.32476	0.274238	0.325843	0.327873	0.324354	0.386896	0.518343	0.534859	0.596047
17	C3	0.163856	0.339679	0.292222	0.319833	0.346834	0.338869	0.339949	0.411098	0.414338	0.436074
	C4	0.154156	0.334728	0.270781	0.337158	0.364827	0.373195	0.391011	0.481846	0.498178	0.535295
18	C3	0.167712	0.339633	0.289337	0.319789	0.346787	0.338823	0.339903	0.411042	0.414282	0.436015
	C4	0.161946	0.334683	0.295162	0.337112	0.364777	0.373144	0.390958	0.481781	0.498111	0.535223

Table 3. Estimations of the mean duration of oscillatory patterns for EEG channels C3 and C4 over the entire monitoring period

№	Channel	Δf_1	Δf_2	Δf_3	Δf_4	Δf_5	Δf_6	Δf_7	Δf_8	Δf_9	Δf_{10}
1	C3	0.241215	0.189902	0.179171	0.079071	0.066564	0.052436	0.046834	0.041146	0.037551	0.032793
	C4	0.273562	0.195762	0.159772	0.108804	0.069397	0.05339	0.049006	0.041283	0.03653	0.031436
2	C3	0.230723	0.205785	0.171124	0.112943	0.071681	0.054471	0.048214	0.043395	0.035691	0.031431
	C4	0.266072	0.200431	0.158794	0.112727	0.075288	0.063899	0.051795	0.042622	0.031564	0.030497
3	C3	0.28565	0.202127	0.153393	0.120501	0.074669	0.060145	0.050986	0.037241	0.031459	0.030405
	C4	0.285836	0.20864	0.154387	0.098184	0.067093	0.063277	0.063876	0.049526	0.036046	0.031471
4	C3	0.284513	0.193001	0.146401	0.094322	0.067881	0.064014	0.058648	0.049281	0.036771	0.030222
	C4	0.281993	0.195362	0.151036	0.100059	0.074576	0.064812	0.055975	0.043418	0.037553	0.033288
5	C3	0.283255	0.213353	0.141691	0.099827	0.068923	0.061068	0.054877	0.042694	0.036497	0.032595
	C4	0.267466	0.209509	0.146054	0.088023	0.064341	0.059269	0.053072	0.045325	0.041158	0.038562
6	C3	0.247931	0.222788	0.145149	0.086555	0.060299	0.051545	0.047428	0.040406	0.038422	0.039497
	C4	0.263377	0.219662	0.140129	0.09218	0.073731	0.066121	0.044043	0.038561	0.037834	0.040087
7	C3	0.274277	0.227333	0.143242	0.098828	0.077009	0.077349	0.053042	0.037433	0.034315	0.035758
	C4	0.262047	0.220321	0.139138	0.152074	0.092489	0.046808	0.043911	0.042471	0.036621	0.033692
8	C3	0.277704	0.213151	0.146204	0.117269	0.087195	0.054042	0.046417	0.043749	0.036306	0.033417
	C4	0.264228	0.214629	0.134168	0.091419	0.072446	0.067568	0.048005	0.037119	0.033455	0.031179
9	C3	0.244206	0.192652	0.138705	0.09586	0.071587	0.063636	0.047559	0.035456	0.029922	0.03341
	C4	0.271477	0.195283	0.13229	0.089947	0.065834	0.054977	0.046769	0.03757	0.03753	0.03519
10	C3	0.252086	0.187062	0.128088	0.08718	0.065605	0.055168	0.043624	0.038445	0.03917	0.037403
	C4	0.281256	0.185841	0.134085	0.089348	0.07394	0.061189	0.047126	0.039987	0.037028	0.034907
11	C3	0.213606	0.195277	0.136107	0.0906	0.065829	0.055842	0.045491	0.039934	0.036675	0.040311
	C4	0.281402	0.202083	0.134252	0.089374	0.074015	0.06119	0.047149	0.039985	0.037039	0.034896
12	C3	0.213606	0.206004	0.136107	0.0906	0.065829	0.055842	0.045491	0.039934	0.036675	0.040311
	C4	0.287581	0.214939	0.137479	0.086165	0.06722	0.057057	0.046013	0.039097	0.034978	0.033599
13	C3	0.271985	0.191954	0.130163	0.087518	0.063481	0.054883	0.043709	0.037893	0.035384	0.034527
	C4	0.288796	0.202675	0.137267	0.086183	0.067233	0.057072	0.046012	0.039115	0.034983	0.033563
14	C3	0.271918	0.189923	0.130145	0.087506	0.063472	0.054875	0.043702	0.037892	0.035422	0.034497
	C4	0.241215	0.187726	0.179171	0.079071	0.066564	0.052436	0.046834	0.041146	0.037551	0.032793
15	C3	0.273562	0.205102	0.159772	0.108804	0.069397	0.05339	0.049006	0.041283	0.03653	0.031436
	C4	0.230723	0.199677	0.171124	0.112943	0.071681	0.054471	0.048214	0.043395	0.035691	0.031431
16	C3	0.266072	0.205174	0.158794	0.112727	0.075288	0.063899	0.051795	0.042622	0.031564	0.030497
	C4	0.28565	0.199424	0.153393	0.120501	0.074669	0.060145	0.050986	0.037241	0.031459	0.030405
17	C3	0.285836	0.188105	0.154387	0.098184	0.067093	0.063277	0.063876	0.049526	0.036046	0.031471
	C4	0.284513	0.19666	0.146401	0.094322	0.067881	0.064014	0.058648	0.049281	0.036771	0.030222
18	C3	0.281993	0.188175	0.151036	0.100059	0.074576	0.064812	0.055975	0.043418	0.037553	0.033288
	C4	0.283255	0.196633	0.141691	0.099827	0.068923	0.061068	0.054877	0.042694	0.036497	0.032595

Discussion

Modern technical achievements – miniaturization of electronics, active introduction of wireless technologies that eliminate many problems of signal filtering, etc., open many new opportunities for medicine to develop interdisciplinary approaches to the analysis of functional signals. However, for obvious reasons, recording the electrical activity of the brain of newborns is still a difficult technical task, primarily due to the impossibility of achieving patient cooperation at this period of life.

The traditional view of neonatal EEG focuses on the visually observable transformation of the EEG from a conventionally «intermittent» to a «continuous» EEG [15-17], while interest in the more detailed characteristics of the brain EEG in adulthood is more varied. In general, today EEG is still used in neonatal care to assess encephalopathy, seizure recognition and classification, to make epilepsy syndrome diagnoses and to assess the maturity of neonatal brain activity. However, neonatal EEG still has a distinct lack of sensitivity in detecting or predicting various mild neurocognitive deficits [18-20].

At the same time, the development of cumbersome technologies that rely on the registration of full EEG recordings combined with other neuroimaging techniques seems to be somewhat of a dead end. Increasing the burden on the primary medical link when conducting such studies will put almost insurmountable obstacles before their actual implementation in clinical practice [21]. In connection with this fact, in the presented study the required number of channels of recorded electroencephalography was reduced to two. It should be noted that the location of these channels in the projection of the central sulcus also seems to be very convenient for installation and fixation of the necessary sensors. The whole proposed algorithm of EEG processing is performed automatically without the need to involve an expert. Of particular importance to the obtained results is the fact that the studied subtle EEG parameters do not depend on the child's sleep/wake state, i. e. they are extremely stable characteristics of brain activity.

Thus, modern science-intensive methods of EEG analysis used in basic science laboratories are at the stage where they can be transferred to the clinical environment for objective assessment of EEG activity. Further adoption of clinical applications is highly dependent on the determined efforts and willingness of the clinical community.

Conclusion

In the framework of the presented work, the detection of characteristic features of oscillatory electrical activity of the brain in the first day of postnatal life depending on the weight of newborns was carried out. All newborns were divided among groups 1 (weight: 2850-4000 gr), and 2 (weight: 2000-2800 gr), and 3 (1200-2000 gr). The results of numerical processing of relative short-term monitoring of electrophysiologic activity of newborns demonstrated statistically significant changes in the band [4; 6] Hz for groups 1-3. In addition, the correlation between the characteristics of the oscillatory pattern in this frequency region and the weight of the newborn child was demonstrated. The results obtained can be used for further longitudinal studies of the influence of early features of neurophysiological activity on neurological and neuropsychological development in older age.

Acknowledgements

This work was supported by the Russian Science Foundation (Project 22-22-00517).

Authors Contributions

Conceptualization – AER; funding acquisition – AER; data curation – YAZ, ENE; resources – AER, YAZ; project administration – AER, YAZ; supervision – EED, YAZ; clinical study – ENE; validation – YAZ, EED; writing-review and editing – AER, YAZ, EED.

Data Availability

The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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