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RESEARCH

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QEEG findings in adolescents complaining of headache

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Abstract

Background Headache is one of the most common neurological symptoms reported in adolescence. The value of electroencephalography (EEG) in the diagnostics of patients with headache is controversial; however, quantitative EEG (QEEG) can clarify the pathophysiology of headache. Aim of the study was to assess QEEG and daily habits in adolescents with or without a clinical history of headache (according to answers of a screening questionnaire), to identify differences, attempt to explain them, and find possible correlations. This cross-sectional study included 89 adolescents; age 18–19 years at time of study, including 24 males. Headache was reported in 58 participant. All consenting subjects filled a questionnaire and underwent a conventional 30 min EEG examination. The mean frequency (Hz) and amplitude (μV) (absolute and relative) of beta (at F7and F8), theta (at C3 and C4), and alpha (at O1 and O2) band points were analyzed.

Results A comparison of caffeine intake, and mobile phone use in cases versus controls showed no significant differences. QEEG showed statistically significant differences in the findings within alpha freq-O1, alpha freq-O2, and beta freq-F7 ($P = 0.041$, 0.003, and 0.05, respectively) in adolescents who had headache.

Conclusions There were significant QEEG changes in the occipital regions and left frontal region in individuals with headache. It is recommended to perform more extensive statistical correlations between QEEG and clinical data should be targeted in future researches, to obtain a clearer view of the relationship between daily habits and the electrophysiology of headache.

Keywords Headache, QEEG, Daily habits, Caffeine, Mobile phone

Background

Primary headaches have long been associated with significant functional impairment of social and work activities [1]. Headache is one of the most common neurological symptoms reported in adolescence, leading to high levels of academic absence. Moreover, it is associated with several comorbid conditions, particularly in the neurological, psychiatric, and cardiovascular systems [2].

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The value of electroencephalography (EEG) in the diagnostics of patients with headache is controversial. Although it is not useful in the routine evaluation of patients with headache [3], EEG can clarify the pathophysiology of this condition, as headache has been quantified objectively via quantitative frequency analysis of EEG (QEEG) in the last decades [4].

Caffeine molecules are considered competitive inhibitors. They resemble adenosine and attach to its receptors at the cell surface, yet with no activation. The most abundant adenosine receptor subtype throughout the brain and spinal cord is A1 adenosine receptors, showing greatest affinity to caffeine. Adenosine suppress cortical excitability by stopping the release of excitatory neurotransmitters [5].

Metabolic deviations from normal that may increase primary headache, in addition to triggering analgesic overuse headache are both possible outcomes of protracted caffeine overuse [6]. Caffeine is effective through strong vasoconstriction, prostaglandin synthesis cessation, and enhanced absorption of other analgesics [7].

Smokers are more likely to have headache. This likelihood significantly increases with the increase in the number of cigarettes smoked daily and pack-years of smoking [8]. Another study demonstrated that tobacco smoking produces widespread bilateral neocortical stimulant effects via the action of nicotine on the brainstem reticular activating system [9].

Wang and colleagues performed a systematic review and meta-analysis of mobile phone usage and the risk of headache and concluded that mobile phone users had an increased risk of headache compared with non-users [10]. Experimentally, headache was the most frequent side effect of cell phone usage, followed by irritation and drowsiness, although these factors were not significantly related to the duration of the use of mobile phones [11].

We aimed to assess quantitative EEG in adolescents with or without a clinical history of headache (according to answers of a screening questionnaire), to identify differences, attempt to explain them, and uncover possible correlations to daily life habits.

Methods

This cross-sectional study recruited healthy adolescents who attended to the clinical neurophysiology unit, EEG laboratory, in our university hospitals. The EEG study was a pre-requisite investigation, as required for enrollment in the first academic year of their faculty. The study was approved on 9.1.2022 to the faculty research ethics committee (REC) with I.D: N-107-2021. As well, the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments. Written informed consent was signed by all participants.

The studied sample included 89 adolescents (18–19 years), 26.97% were males. The sample was subdivided to (a) the case group, with a history of headache (58 subjects; 18 males), and (b) the normal control group (31 subjects; 6 males).

All consenting subjects filled a screening questionnaire which was designed by one of the authors in Arabic. The items in the questionnaire included inquiries about age, handedness, caffeine intake, cigarette smoking, smart phone usage and about headache. Further analysis of headache includes duration of the complaint, description, location, associated symptoms, rate of occurrence, intensity of headache, whether the participant is having headache during questionnaire filling, the impact of headache on daily life, whether analgesics is used, the presence of any associated illnesses and if there is family history of headache (Additional file 1).

All subjects underwent a conventional 30 min EEG examination using an EBNeuro Galileo NT Patient Management System (PMS) machine (model, Mizar B8351037899 (version 3.61); USA) at the Clinical Neurophysiology Unit. Electrode application was performed according to the International 10/20 electrode placement system. The high-frequency filter used was 70 Hz, and the time constant was 0.3 s. The screen speed was 10 s/screen. Provocation procedures included intermittent multi-rhythmic photic stimulation and 3 min of hyperventilation. QEEG was analyzed on the same machine using the WinEEG software. Epochs of the filtered EEG with excessive amplitude (> 100 μV) and/or excessively fast (> 35 μV in the 20–35-Hz band) and slow (> 50 μV in the 0–1 Hz band) frequency activities were automatically marked and excluded from further analysis. EEG was visually inspected to verify any abnormal discharges and artifacts.

The mean frequency (Hz) and amplitude (absolute and relative—μV) of beta (at F7and F8), theta (at C3 and C4), and alpha (at O1 and O2) points were analyzed. Moreover, the power (μV^2) of all waves (delta, theta, alpha, and beta) was analyzed in the occipital electrodes.

The study included all consenting participants. However, 15 EEG records with non-satisfactory technique were excluded from the study. In addition, EEG results of 2 participants with hypertension were not included in the statistical analysis.

Data were statistically described in terms of mean ± standard deviation (± SD), median and range, or frequencies (number of cases) and percentages when appropriate. Numerical data were tested for the normal assumption using Kolmogorov Smirnov test [12]. Comparison of numerical variables between the study groups was done using Student *t* test for independent samples in comparing normally distributed data and Mann Whitney *U* test [13] for independent samples for comparing not-normal data. For comparing categorical data, Chi-square (χ^2) test [14] was performed. Exact test was used instead when the expected frequency is less than 5. Correlation between various variables was done using Spearman rank correlation equation [15] Two-sided *p* values less than 0.05 was considered statistically significant. All statistical calculations were done using computer program IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) release 22 for Microsoft Windows.

Results

This study recruited 89 adolescents with age range 18–19 years, including 24 males (26.97%). Subjects were divided into two groups according to whether they reported a clinical history of headache or not: the case group, with a history of headache (58 subjects), and the normal control group (31 subjects). Male/female ratio was 6/25 and 18/40 in control and cases groups, respectively, with no statistical significant difference between both groups regarding gender distribution.

The case group encompassed 18 males (31.03%). Regarding the intake of caffeinated drinks (coffee or tea), 32 subjects mentioned ingesting only one or two cups per day, with only one subject ingesting 3–5 cups per day and another participant ingesting more than 5 cups per day. Smart phone usage was < 2 h per day in 20 subjects and 2–6 h per day in 30 subjects. Only two participants reported hypertension (3.45%), with no further provided details. Moreover, 12 subjects (20.69%) confirmed a family history of headache in a first-degree relative. None of the participants reported cigarette smoking. Thus, further numeric analysis for this daily habit was not proceeded.

The control group included six males (19.3%). Regarding the intake of caffeinated drinks (coffee or tea), 12 subjects mentioned ingesting only one or two cups per day, whereas only one subject smoked less than 10 cigarettes per day. Smart phone usage was reportedly < 2 h per day in 12 subjects, 2–6 h in eight subjects, and > 6 h in only one subject. Two subjects (6.45%) confirmed a family history of headache in a first-degree relative. The comparison of caffeine intake, and mobile phone usage in cases versus controls showed no significant differences ($P = 0.060$, and 0.084, respectively (Table 1).

In the case group, headache analysis items, as answered in the questionnaires are presented in Table 2.

No significant correlations were found between the consumption of caffeine and mobile phone usage and the frequency of headache or the effect of headache on daily life (Table 3).

Table 1 Comparison of caffeine intake and mobile phone use between cases versus controls

Group	Mean rank %	Sum of ranks	*P* value
Caffeine intake			
Controls	38.84	1204.00	0.060
Cases	48.29	2801.00	
Mobile phone usage			
Controls	38.97	1208.00	0.084
Cases	48.22	2797.00	

No significant differences

Table 2 Headache analysis items (as in questionnaire)

Headache analysis items (as in questionnaire)	
Duration (n = 17)	
< 1 month	6 (35.29%)
1–12 months	9 (52.94%)
> 12 months	1 (5.88%)
Type (n = 43)	
Pulses	18 (41.86%)
Pressure	12 (27.91%)
Numbness	4 (9.30%)
Burning	1(2.33%)
Pickling	0
Others	8 (18.60%)
Location (n = 46)	
Front of the head	25 (54.35%)
Back of the head	5 (10.87%)
In the eyes	7 (15.22%)
In the neck	1 (2.17%)
Rt side migraine	7 (15.22%)
Lt side migraine	1 (2.17%)
Other symptoms N = 45	
No	43 (95.56%)
Yes	2 (4.44%)
Severity (n = 34) From 1 to 10	
Max	8
Min	1
Average	3
Frequency (n = 39)	
Daily	3 (7.69%)
Weekly	6 (15.38%)
Monthly	14 (35.90%)
Others	16 (41.03%)

Table 3 Correlation between the consumption of caffeine and mobile phone use versus the frequency of headache and the effect of headache on daily life

	Headache frequency	**Effect on daily life**
Spearman's rho		
Caffeine consumption		
Correlation Coefficient	0.047	0.233
P value	0.753	0.081
n	47	57
Mobile phone usage		
Correlation Coefficient	− 0.160	0.165
P value	0.282	0.220
n	47	57

n number

The quantitative EEG (QEEG) findings were assessed in 72 records, after exclusion of technically unsatisfactory ones (15 record), as well as 2 records for participants patients with hypertension. The QEEG in the two groups (headache (48 records) and control groups (24 records) showed statistically significant differences in the findings within alpha freq-O1, alpha freq-O2, and beta freq-F7 ($P=0.041$, 0.003, and 0.05, respectively). The amplitude (absolute or relative) was not significantly different between the groups (Figs. 1, 2).

A significant positive correlation was detected between caffeine intake and beta freq-F7 ($P=0.008$) and a positive correlation was observed between mobile phone usage and alpha freq-O1 ($P=0.012$). (Table 4). However, there was no correlation between the frequency of headache and any of the QEEG variables.

Discussion

Our study revealed a significant positive correlation between caffeine intake and the beta frequency in F7 and headache. This was not in line with a previous study of the effect of caffeine on EEG, that showed a reduction in absolute power, especially in the alpha band, on the entire scalp [15]. Yet, a pathophysiological support to our results was mentioned earlier. It highlighted that caffeine induces a state of cortical hyperexcitability because of its inhibitory effect on adenosine receptors; this process increases alertness and improves cognitive function [5].

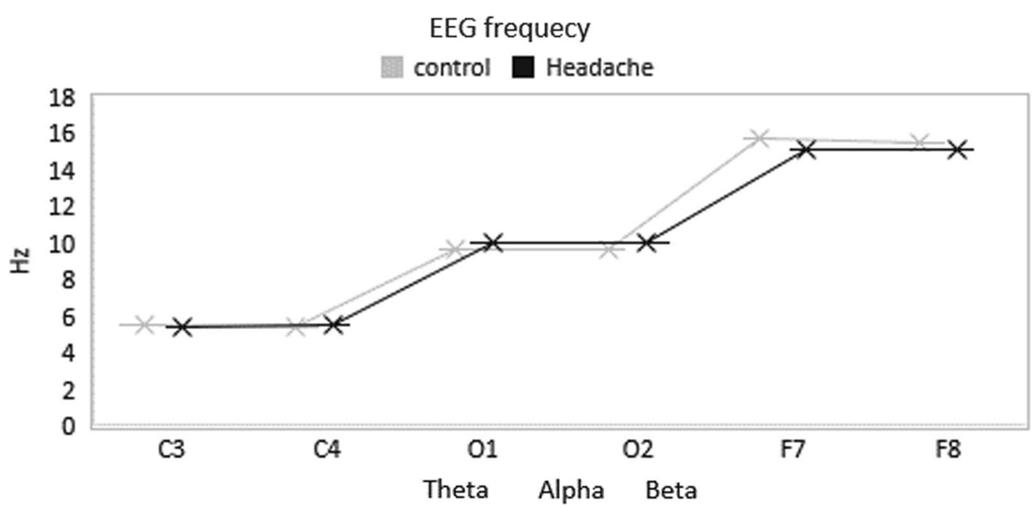

Fig. 1 Quantitative EEG frequency of the theta band at C3 and C4, the alpha band at O1 and O2, and the beta band at F7 and F8 in the two groups

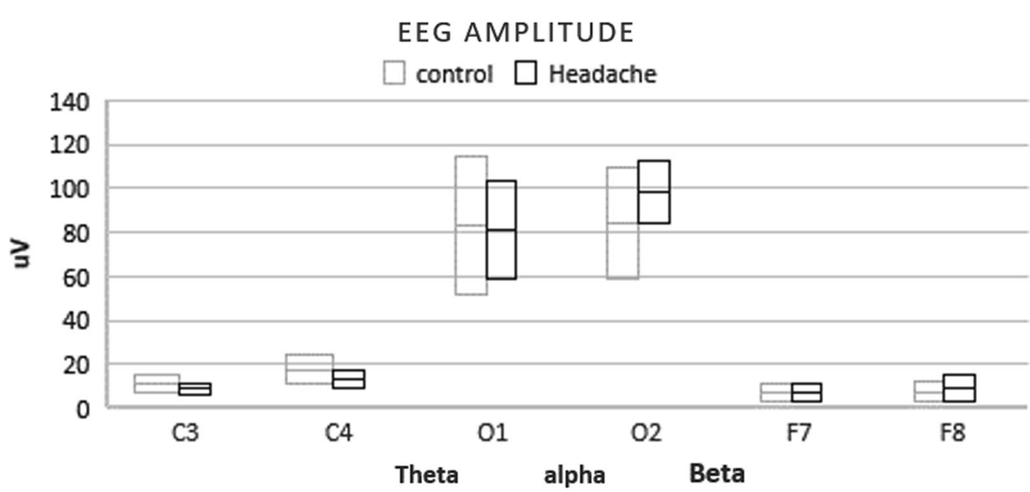

Fig. 2 Quantification of the absolute and relative EEG amplitude of the theta band at C3 and C4, the alpha band at O1 and O2, and the beta band at F7 and F8 in the two groups

Table 4 Correlation between quantitative EEG data and daily habits

	Alpha frequency Q1	Alpha frequency Q2	Beta frequency F7
Caffeine intake			
Correlation coefficient	−0.165	−0.143	0.380
P value	0.262	0.332	0.008*
n	48	48	48
Mobile phone usage			
Correlation coefficient	0.358	0.277	−0.136
P value	0.012*	0.056	0.357
n	48	48	48
Frequency of headache			
Correlation coefficient	−0.016	−0.23	0.075
P value	0.923	0.209	0.646
n	40	40	40
Effect on daily life			
Correlation coefficient	−0.018	0.006	0.104
P value	0.902	0.968	0.487
n	47	47	47

n number, *=significantly different

Our study also showed no correlation between caffeine intake and the frequency of headache or the effect of headache on daily life. An earlier study examined the impact of caffeine abstinence on cerebral blood flow velocity via quantitative EEG. Changes in cerebral blood flow velocity, together with quantitative EEG changes (increased EEG theta power) were appreciated. Both may be bonded to the prevalent caffeine withdrawal symptoms; headache, drowsiness, and diminished alertness [6].

Our study revealed as well an absence of correlations between cell phone usage and the frequency of headache or the effect of headache on daily life. However, at the electrophysiological level, our study showed a positive correlation between mobile phone usage and alpha frequency in O1 in patients with headache. This may be explained by our assumption that the increased mobile usage observed among this age group is accompanied by further activation of the dominant cortex–occipital lobe.

Although the simultaneous occurrence of usage of an active mobile phone and EEG recording was not adopted in our methodology, it is of interest to highlight that frontal slow waves were detected most often in Parmar's study group, probably because this area might be the one showing the strongest effect for the attention that is necessary once the phone is in use, but also probably because of some effect of the electromagnetic waves themselves on the brain [11]. Similarly, other researchers have reported a subtle slowing of brain activity related to mobile phone use [16]. However, in a previous study that was co-authored by one of the authors of the current study, a 30-min mobile phone call evoked no EEG changes in normal individuals or patients with epilepsy with normal baseline EEG recordings [17].

A cohort study of mobile phone usage and health including more than 20,000 participants concluded that people who used mobile phones most extensively for making or receiving calls reported weekly headaches slightly more frequently at follow-up than did other users. However, this cohort study reported confounders; the risk of headache was increased in those who had longer daily mobile phone call duration and higher daily call frequency [18].

It is to be noted that only two of our patients (3.45%) had headache coinciding with the EEG recording. In addition, our results, as earlier mentioned showed a significant difference in alpha frequency in O1, alpha frequency in O2, and beta frequency in F7 between the patient and control groups. Previous studies using EEG at rest and during the headache attacks indicated that, upon the onset of headache, there were evident changes in the frequency and amplitude of alpha bands, as well as the presence of diffused theta and delta waves in the brain. [19, 20]. This is potentially similar to our findings.

All our patients had essentially normal EEG recordings. Moreover, the absolute majority of our recordings did not coincide with headache attacks. However, in Hashemi and colleagues study 1- of 4 cases showed generalized paroxysmal epileptiform activity coinciding with headache peak. Interestingly, that case had no epileptic clinical background with unaltered alertness and orientation and those EEG changes were absent when the EEG was repeated off-headache. [21]

It is worth to mention that the participants in the current study did not mention about any excessive caffeine intake, cigarette smoking or cell phone over usage. Thus, the study could not suggest or advise any change in the daily habits in such age group. Those replies, somewhat, surprised the research team, as they are not in line with three relevant Egyptian researches. For instance, it was concluded that the consumption of caffeine containing drinks among Alexandria University students was very high and exceeded the safe levels [22]. In addition, a previous study estimated that 34% of Egyptians are daily smokers, 4% of whom are under the age 15 years and 0.6% of whom are under the age 10 [23]. Finally, a study showed that about 59% of the Egyptian university students are smartphone addicts without any gender difference [24].

It is to be noted that the study results were based upon the EEG findings as well as the replies of the participants to the questionnaire constructed before the initiation of the study by one of the coauthors, and was not modulated as the study proceeded. This, unfortunately, impeded the detailed description of the study sample.

The study was limited by the fact of being cross-sectional. There was no information about the headache diagnosis or management, apart from the subjective responses (or self-reporting) of the study participants.

Conclusion

Significant QEEG changes in the occipital regions and left frontal region in adolescence complaining of headache was observed. Thus, we are recommending future researches with larger sample size, which assess additional daily life habits and include other headache-classifying inquiries through validated questionnaires.

Abbreviations

C	Central
EEG	Electroencephalography
F	Frontal
O	Occipital
PMS	Patient management system
QEEG	Quantitative electroencephalography
±SD	Standard deviation

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41983-023-00657-z.

Additional file 1. Arabic headache questionaire; constructed by HA; used in the research.

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Author contributions

SE: contributed to study design, data analysis and interpretation, scientific writing. HA: contributed to study design, data analysis and interpretation, scientific writing. MB: contributed to study design, subjects' recruitment, contributed to data analysis and interpretation, scientific writing, and corresponding author. AS: contributed to data analysis and interpretation, contributed to scientific writing. All authors read and approved the final manuscript.

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Availability of data and materials

The data sets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the research ethics committee (REC) of Faculty of Medicine, Cairo University; approval number (N107). The study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments. Participation written informed consent was signed by all participants.

Consent for publication

Not applicable; no individual details, images or videos were included in the study.

Competing interests

The authors declare that they have no competing interests.

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