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Electroencephalographic Abnormalities in Children with Attention Deficit Hyperactivity Disorder without Known Epilepsy – A Cross Sectional Study

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Abstract:

Background: *Attention deficit hyperactivity disorder (ADHD) is a common problem in the field of Pediatric neurology and psychiatry, often accompanied by various comorbidities such as epilepsy. Electroencephalography (EEG) abnormalities are frequently observed in a certain proportion of ADHD cases. This study aimed to observe the EEG abnormalities in children with ADHD without known epilepsy.*

Materials and Methods: *A cross-sectional study was carried out at the Institute of Pediatric Neurodisorder and Autism (IPNA), Bangabandhu Sheikh Mujib Medical University (BSMMU) over a 12-month period from July 2020 to June 2022. Participants included children aged 3-15 years diagnosed with ADHD based on DSM-5 criteria. Individuals with neurodegenerative disorders, epilepsy, visual or hearing impairments, cerebral palsy, or other neurobehavioral disorders were excluded. Ethical clearance was obtained from the Institutional Review Board (IRB) of BSMMU prior to the study, and written consent was obtained from parents/caregivers. EEG evaluations were conducted on all participants over a 30-minute period, encompassing both sleep and wakefulness, with activation procedures during recording.*

Results: *Seventy children diagnosed with ADHD were enrolled, with a mean age of 7.41±2.86 years and a male-to-female ratio of 4:1. ADHD sub types included primarily inattentive (8.6%), primarily hyperactive/impulsive (28.6%), and combined type (62.9%). Normal EEG recordings were observed in 60% of children, while abnormal recordings were found in 40% of cases. Among those with abnormal EEG findings, 3.6% were primarily inattentive, 39.3% were primarily hyperactive/impulsive, and 57.1% were of the combined type. Generalized epileptiform discharges were present in 14.3% of children, and focal epileptiform discharges in 20%.*

Conclusion: *The study concluded that abnormal EEG findings were prevalent in children with ADHD even in the absence of clinical seizures or epilepsy. EEG evaluation should be considered for the proper management of children with ADHD.*

Key words: *ADHD, Electroencephalography (EEG), Children.*

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Introduction:

Attention deficit hyperactivity disorder (ADHD) presents with impulsivity, short attention time and hyperactivity, which is a common problem in pediatric neurology and psychiatry[1]. It has a prevalence rate of approximately 7%-9% in children and 2.5%-4% in adults with a male predominance [2].

Several neurological, neuropsychiatric, and disruptive behavior disorders often coexist with ADHD. These include specific learning disorders, anxiety disorders,

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depressive disorders, deficits in executive functioning abilities, oppositional defiant disorder, and conduct disorders[3].

One of the common neurological associations of ADHD is epilepsy. Cohen et al[4] and Dunn et al.[5] reported prevalence of ADHD from 23% to 40% in children with epilepsy and, compared to 3-6% of the general population. On the other hand, epilepsy has been found in 14% of children with ADHD[6]. The relationship between epilepsy and ADHD is a two-way street. The symptoms of epilepsy may overlap with features of ADHD.

It has also been found that in a group of children with severe epilepsy and combined ADHD, the presentation was more likely to have generalized epilepsy, an earlier age of onset, and a lower level of functioning.[7]

Children with ADHD and epilepsy are at risk for additional emotional, behavioral, and cognitive problems. ADHD has also been associated with learning difficulties[8]. These factors have a significant impact on the social and academic performances of these children.[9]

Electroencephalographic (EEG) abnormalities in children with ADHD appears to be more expected than that of the normal population[10]. The presence of epileptic activity in EEG in the children with ADHD have been reported with a wide range of variation from 6.1 to -26%[1]. Parisi et al [11,12] reported abnormal EEG discharge in 5-60% of children with ADHD and among them 10-20% were epileptiform. EEG abnormalities may be present even in the absence of clinical seizure or epilepsy;[13] abnormal EEG findings is found in about half of children among the discharges, epileptiform discharges is about a quarter of patients with ADHD. He emphasized taking family history of seizures and the importance of doing EEG. Subclinical Paroxysmal Activity (PA) may also be accompanied by subtle impairments of attention shown by changes in reaction time during simultaneous EEG [14]. EEG has a significant potential for planning and monitoring of treatment. Moreover, it can help to evaluate the most treatable comorbidity. But very few studies has been done keeping the importance on EEG abnormalities. Thus, the current study was designed to conduct critical analysis of EEG abnormalities among the ADHD children without epilepsy.

Materials & Methods:

This cross-sectional study was conducted at Pediatric Neurology, IPNA, BSMMU, during July 2020 to June 2021. Children between the ages of 3-15 years who visited at IPNA OPD with the clinical features of ADHD (hyperactivity, inattention) were sent to assigned clinical psychologist to do DSM -5 for ADHD. Patients were classified based on the types of symptoms into three categories, combined presentation (ADHD-C), predominantly inattentive presentation (ADHD-I) and predominantly hyperactive-impulsive presentation (ADHD-H) using DSM-5 for ADHD.

Gender, age, symptoms associated with ADHD, family history of similar illness and neurological-systemic disease were recorded. An informed written consent was obtained from parent/caregiver of each of the child. Before commencement of the study ethical clearance was obtained from Institutional review board (IRB) of BSMMU.

All children and their attendant/parents were informed about the EEG procedure. Both sleep and/or awake EEG recording was done from all children, and recording time was 30 minutes. Photic stimulation and hyperventilation were used during EEG recording as provocation. Scalp EEG electrodes was placed according to the International 10-20 system. After completion of EEG, all recordings were reported by expert pediatric neurophysiologist and the findings were noted carefully. In awake state, lack of posterior dominant wave, slowing, nonresponsive to external stimuli was taken as abnormal background activity. In sleep, lack of sleep marker, focal or generalized diffuse slowing or attenuation, discontinuity was taken as abnormal. Focal or generalized discharge with spike and sharp wave followed by slow wave was considered as epileptiform discharge. All the data were recorded in a pretested data sheet/ questionnaire form. Highest level of confidentiality and ethical standard was maintained during storage and analysis of the data.

Data analysis: Data were computed in SPSS version 22.0, data were cleaned and processed. Demographic variables were analyzed as frequencies. Categorical variables were analyzed by chi square test, continuous variables were analyzed by t test. Results were presented in tabulated form and chart.

Results

Total 70 children diagnosed with ADHD were enrolled in this study, all of them completed awake and sleep EEG evaluations. None of them received any stimulant medication before.

Table I shows total 80 children with ADHD were enrolled. Among them majority were male (80%).

Table-I

Demographic characteristics of studied subjects

Character	n (%)
Total children	70(100)
Types of ADHD	
ADHD-I	6(8.6)
ADHD-HI	20(28.6)
ADHD- C	44(62.9)
Mean age (Years)	7.41±2.86
Sex	
Male	56 (80)
Female	14 (20)
Residence	
Urban	48(68.6)
Rural	22(31.4)

Abbreviations ADHD, attention deficit hyperactivity disorder
ADHD-I, attention deficit hyperactivity disorder, predominantly Inattention
ADHD HI, attention deficit hyperactivity disorder, predominantly Hyperactive-Impulsive
ADHD-C, attention deficit hyperactivity disorder, combined

Attention deficit combined type was the most prevalent type (62.9%) in these children.

Figure 1 shows the age distribution of the study population. In this study, the highest number of children (18.6%) were diagnosed in age 7 years. About two third (67.3%) of children were diagnosed within 8 years of age. Mean age 7.41±2.86.

Figure 2 shows various sub types of ADHD in studied children, where 6 (8.6%) were the primarily inattentive type, 20 (28.6%) were the primarily hyperactive/ impulsive type, and 44(62.9%) were the combined type of ADHD.

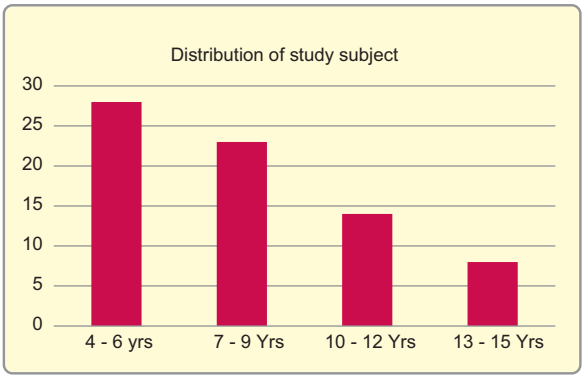

Figure 1: *Distribution of studied subject according to age*

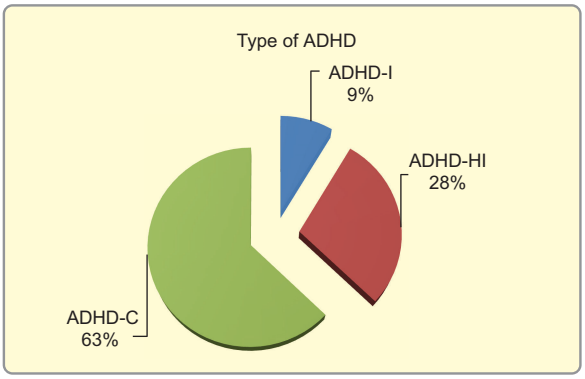

Figure 2: *Pie chart showing types of ADHD among of studied children.*

Table II shows 2.9% has history of neonatal Seizure. Neonatal Jaundice, encephalitis and head injury all had 1.4% in each group. Family h/o ADHD 5.7%). History of febrile seizure was present in 11(15.7%) children.

Table III shows EEG profile of study population. Normal EEG recordings were found in 42 (60%) of the patients, and abnormal recordings in 28 (40%). EEG finding shows, 62(88.6%) patients having normal background on EEG and 4(5.7%) having slowing, 1(1.4%) high voltage, 3(4.3%) had faster background. On EEG recordings, 10 (14.3%) had generalized epileptiform discharges and 14 (20%) had focal epileptiform discharges. The focal epileptiform discharges were most prevalent from the temporal area (6, 8.6%), followed by the frontal area (3,4.3%), parietal-temporal area (2,2.9%) fronto-parieto-temporal (1,1.4%) and temporal-parietal-occipital occipital area (1,1.4%) considering all patients.

Table-II

Risk factors related to ADHD of studied children (n=70)

Risk factors	N (%)
Insult to brain	
No event	47(67.1)
Neonatal Seizure	2(2.9)
Neonatal Jaundice	1(1.4)
Encephalitis	1(1.4)
Head injury	1(1.4)
Consanguinity	9(12.9)
Family history of ADHD	4(5.7)
History febrile seizure	11(15.7)

Table-III

EEG profile of children with ADHD (N=70)

	N (%)
EEG	
Normal	42(60)
Abnormal	28(40)
Background	
Normal	62(88.6)
Slowing	4(5.7)
High voltage	1(1.4)
Fast	3(4.3)
Epileptiform discharge	
No	46(65.7)
Yes	24(34.3)
Focal	14(20)
Generalized	10(14.3)
Origin of focal Epileptiform discharge	
Frontal	3(4.3)
Temporal	6(8.6)
Parieto-occipital	1(1.4)
Parieto-temporal	2(2.9)
Fronto-Parieto-temporal	1(1.4)
Temporal-parietal-occipital	1(1.4)

Figure III shows focal epileptiform discharge from temporal area in 43% of cases, followed by 21%, 15% and 7% from frontal, parieto-temporal and multiple areas respectively.

Figure IV shows out of 28 children with abnormal EEG recordings, 1 (3.6%) were the primarily inattentive type, 11 (39.3%) were the primarily hyperactive/impulsive type, and 16 (57.1%) were the combined type of ADHD.

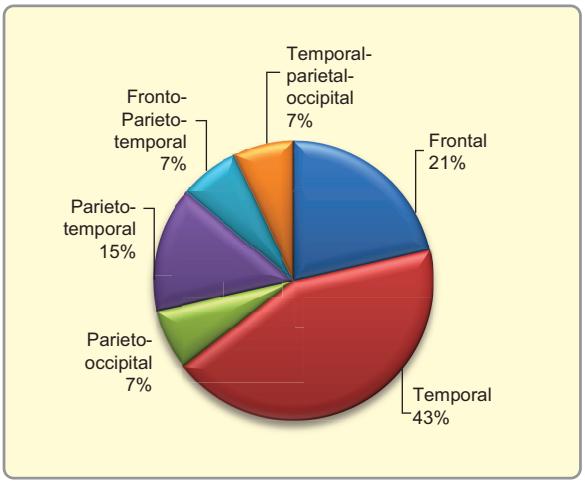

Figure 3: *Pie chart showing site of origin of focal epileptiform discharge found in EEG*

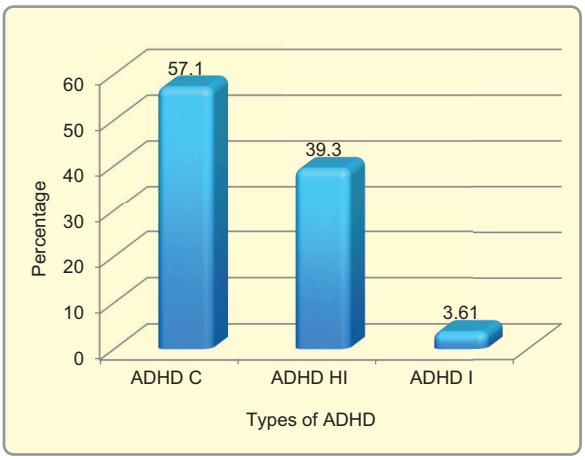

Figure 4: *EEG Abnormalities among ADHD sub types.*

Table IV showing the comparison of EEG findings among types ADHD. Here abnormal EEG findings were more in ADHD-C group but in compare to other was not statistically significant.

Table-IV

Comparison of EEG findings among types of ADHD

	ADHD-I n(%)	ADHD-HI n(%)	ADHD-C n(%)	P value
	6(100)	20(100)	44(100)	
EEG				
Normal	5(83.3)	9(45)	28(63.6)	0.176
Abnormal	1(16.7)	11(55)	16(36.4)	
Background				
Normal	5 (83.3)	17(85)	40(90.9)	0.059
Slowing	0 (0)	2 (10)	2 (4.5)	
High voltage	1	0	0	
Fast	0	1(5)	2(4.5)	
Epileptiform discharge	5(83.3)	10(50)	31(70.1)	0.371
No	1(16.7)	5(25)	8(18.2)	
Focal	0	5(25)	5(11.4)	
Generalized				

*Chi-square test done, P value < 0.05 consider significant

Discussion:

This study has been done with an attempt to find out the EEG abnormalities of children with ADHD without epilepsy. Mean age of this study population was 7.41±2.86years, ranging from 4 to 14 years (Table 1). This finding agrees with those of, Raif et al [1] and Gupta et al.[15]. Male-to female ratio was 4:1 in this study; Li YW et al also observed this ratio in their study[12]. This ratio was low less in few other studies like Raif et al. & Polanczyk et al. and high in a study by Venkatesh C et al.[1],[16],[17]. Referral biases among treatment-seeking patients or to sex-specific effects of ADHD over the course of the disorder could be the cause of high number of male patients presented here.

This study found, 68.6% of children were from urban area, and 31.4 from rural background. These findings are almost similar to that of Gupta et al.[15].

In 11.4% cases, history of perinatal asphyxia was found and, 67% had no history of any insult in the perinatal period (Table II). History of consanguinity was present in 9 cases. In ADHD subtypes, combined type of ADHD was found at a higher percentage (62.9%), this was followed by primarily hyperactive/impulsive type (28.6%) and inattentive type (8.6%) (figure2). But Wolraich et al found almost equal percentage for all the three types in their epidemiological studies[19]. The finding of more severe types of ADHD (combined type) may be a reflection of the fact that this study was carried out in a tertiary care hospital, which could explain why it differs from an epidemiological study, since the most difficult cases are usually sent in these hospitals.

In this study, the prevalence of EEG abnormalities was observed in 40%(28/70) of cases. Among them 34.3% (24/70) were epileptiform discharges and 11.43% (8/70) had background abnormality (Table III). This finding is more or less similar with the finding by Raif SG et al [1]. But Kanazawa et al found higher EEG abnormalities than this (48%)[13]. On the other hand, Yi-Wei, Chen and Hung et al found lower percentage (23%) in their study[12]. The wide variation in the frequency of EEG abnormalities may be due to different research methods, duration of EEG recording, EEG activation, and the enrolled study subjects.

Here in this study, more focal epileptiform discharges (20%) were found than generalized epileptiform discharges (14.3%). Li YW et al. and Raif et al. also found focal epileptiform discharge (89% and 62% respectively) more compared to generalized epileptiform (10.7% and 38%) discharges[12],[1]. The focal epileptiform discharges were most prevalent from the temporal area

42% (6/14), followed by the frontal area 21% (3/14), parietal- temporal area 14% (2/14) fronto-parieto-temporal 7% (1/14) and temporal-parietal-occipital occipital area 7% (1/14). Li YW et al. found focal epileptiform discharges as the most common, arising from Rolandic (centro-temporal) *area*, followed by the parietal and frontal areas[12]. Zaimoglu et al.[20], reported, higher epileptiform abnormalities from frontal area (41.0%).Previous studies have demonstrated functional alterations in the frontostriatal circuit and changes in the cerebellum and parietal lobes[21], [22]. However, epileptiform discharges more from the temporal area found in this and the above-mentioned studies requires further research at a molecular level.

The frequency of EEG abnormalities might not reflect clinical seizures or epilepsy. But epileptiform discharges found in ADHD may suggest subclinical seizures or subsequent seizures[12]. Seizures has been reported in 3 out of 30 children with ADHD with epileptiform discharges compared to one of 175 children without epileptiform discharges[23]. Predictive value of epileptiform abnormalities for the subsequent development of seizure or epilepsy has also been reported children with in few studies[24]. Therefore, children with ADHD having abnormal EEG recordings should have long-term clinical follow-up and be carefully evaluated for subclinical seizures or the new onset of seizures. Studies have also observed improvements in cognitive function improvements in clinical symptoms after taking AED in children with ADHD having subclinical epileptiform[25],[26]. However, AED use is still debatable in ADHD without epilepsy and further research is required in this area.

In this study, highest percentage of EEG abnormalities (57.1%) were found in the combined type of ADHD but no statistical significance was found. EEG abnormality was 39.3% in primarily hyperactive/impulsive type and 3.6% in inattentive type (Table IV). This finding is consistent with that of Li YW et al [12], although the percentage found in combined type was much higher in their study than this study finding.

Limitation:

It is a single center study, in a tertiary care hospital. So result of this study could not be generalized. Multi center study may yield more generalized result.

Conclusion:

About 34% children with ADHD had some form of EEG abnormality. These abnormalities are commonly found in combined type. Focal discharges were little higher than generalized discharges.

Recommendation:

EEG should be considered as a routine laboratory investigation in children with ADHD.

Conflict-of-interest: There is no potential conflict of interest.

References:

1. Raif SG, Güngör S, Özcan ÖÖ, Arslan M. Electro-encephalographic Findings in Children with Attention Deficit Hyperactivity Disorder. J Child Adolesc Behav. 2016;4(276):2.
2. Froehlich TE, Brinkman WB. Multimodal treatment of the school-aged child with attention-deficit/hyperactivity disorder. JAMA pediatrics. 2018 Feb 1;172(2):109-10.
3. Willcutt EG, Doyle AE, Nigg JT, Faraone SV, Pennington BF. Validity of the executive function theory of attention-deficit/hyperactivity disorder: a meta-analytic review. Biological psychiatry. 2005 Jun 1;57(11):1336-46.
4. Cohen R, Senecky Y, Shuper A, Inbar D, Chodick G, Shalev V, Raz R. Prevalence of epilepsy and attention-deficit hyperactivity (ADHD) disorder: a population-based study. Journal of child neurology. 2013 Jan;28(1):120-3.
5. Dunn DW, Kronenberger WG. Attention-deficit/ hyperactivity disorder in children and adolescents. Neurologic clinics. 2003 Nov 1;21(4):933-40.
6. Epilepsy Foundation, 2021
7. Sherman EM, Slick DJ, Connolly MB, Eyrl KL. ADHD, neurological correlates and health related quality of life in severe pediatric epilepsy. Epilepsia. 2007 Jun;48(6):1083-91.
8. Aro T, Ahonen T, Tolvanen A, Lyytinen H, de Barra HT. Contribution of ADHD characteristics to the academic treatment outcome of children with learning difficulties. Developmental Neuropsychology. 1999 Jan 1;15(2):291-305.
9. Russ SA, Larson K, Halfon N. A national profile of childhood epilepsy and seizure disorder. Pediatrics. 2012 Feb 1;129(2):256-64.
10. Hodgkins P, Arnold LE, Shaw M, Caci H, Kahle J, Woods AG, Young S. A systematic review of global publication trends regarding long-term outcomes of ADHD. Frontiers in psychiatry. 2012 Jan 18;2:19078.
11. Parisi P, Moavero R, Verrotti A, Curatolo P. Attention deficit hyperactivity disorder in children with epilepsy. Brain and Development. 2010 Jan 1;32(1):10-6.

12. Li YW, Chen HJ, Hung KL. Electroencephalographic abnormalities in non-epileptic children with attention-deficit/hyperactivity disorder. Neuropsychiatry (London). 2018;8(2):677-83.

13. Kanazawa O. Reappraisal of abnormal EEG findings in children with ADHD: on the relationship between ADHD and epileptiform discharges. Epilepsy & Behavior. 2014 Dec 1;41:251-6.

14. Schubert R. Attention deficit disorder and epilepsy. Pediatric neurology. 2005 Jan 1;32(1):1-0.

15. Gupta RK, Sharma P, Banal R, Majeed M, Kumari R, Langer B, Akhter N, Gupta C, Raina SK. Prevalence and correlates of Attention Deficit Hyperactive Disorder (ADHD) risk factors among school children in a rural area of North India. Journal of family medicine and primary care. 2020 Jan 1;9(1):115-8.

16. Polanczyk G, De Lima MS, Horta BL, Biederman J, Rohde LA. The worldwide prevalence of ADHD: a systematic review and metaregression analysis. American journal of psychiatry. 2007 Jun;164(6):942-8.

17. Venkatesh C, Ravikumar T, Andal A, Virudhagirinathan BS. Attention-deficit/hyperactivity disorder in children: clinical profile and co-morbidity. Indian Journal of Psychological Medicine. 2012 Jan;34(1):34-8.

18. Matte B, Anselmi L, Salum GA, Kieling C, Gonçalves H, Menezes A, Grevet EH, Rohde LA. ADHD in DSM-5: a field trial in a large, representative sample of 18-to 19-year-old adults. Psychological medicine. 2015 Jan;45(2):361-73.

19. Wolraich ML, Hannah JN, Pinnock TY, Baumgaertel A, Brown J. Comparison of diagnostic criteria for attention-deficit hyperactivity disorder in a county-wide sample. Journal of the American Academy of Child & Adolescent Psychiatry. 1996 Mar 1;35(3):319-24.

20. Zaimoðlu S, Türkdoðan D, Mazlum B, Bekiroðlu N, Tetik-Kabil A, Eyilikeder S. When is EEG indicated in attention-deficit/hyperactivity disorder?. Journal of child neurology. 2015 Nov;30(13):1785-93.

21. Kooistra L, van der Meere JJ, Edwards JD, Kaplan BJ, Crawford S, Goodyear BG. Preliminary fMRI findings on the effects of event rate in adults with ADHD. Journal of neural transmission. 2010 May;117:655-62.

22. Cherkasova MV, Hechtman L. Neuroimaging in attention-deficit hyperactivity disorder: beyond the frontostriatal circuitry. The Canadian Journal of Psychiatry. 2009 Oct;54(10):651-64.

23. Hemmer SA, Pasternak JF, Zecker SG, Trommer BL. Stimulant therapy and seizure risk in children with ADHD. Pediatric neurology. 2001 Feb 1;24(2):99-102.

24. Lee EH, Choi YS, Yoon HS, Bahn GH. Clinical impact of epileptiform discharge in children with attention-deficit/hyperactivity disorder (ADHD). Journal of Child Neurology. 2016 Apr;31(5):584-8.

25. Gordon K, Bawden H, Camfield P, Mann S, Orlik P. Valproic acid treatment of learning disorder and severely epileptiform EEG without clinical seizures. Journal of Child Neurology. 1996 Jan;11(1):41-3.

26. Miyazaki M, Ito H, Saijo T, Mori K, Kagami S, Kuroda Y. Favorable response of ADHD with giant SEP to extended-release valproate. Brain and Development. 2006 Aug 1;28(7):470-2.