Neuropsychological Assessment and EEG Evaluation of Dyslexic Children

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ABSTRACT

Dyslexia, a specific reading disability, is the most frequent learning disability with a prevalence ranging from 5-15% of school-age children. Dyslexia is unexpected underachievement in reading for one's intellectual ability. The exact etiology of dyslexia, as well as specific sensory deficits in dyslexia, remain controversial. One would therefore expect that there are multiple points within the brain where dysfunction may lead to dyslexia. The aim of this study was to assess the intellectual functions and the neuropsychological profile of a 20 dyslexic children in comparison with 20 normal (non-dyslexic) children and to evaluate the possible factors at the cerebral level that might contribute to the problem of dyslexia as analysis of EEG power density spectra in eight different regions. In the present study, dyslexic children had a mean age of 7.5±1.73 years with highest percentage (50%) at the age group of 8 years. failure of scholastic achievement was almost the first sign for referral. In our study dyslexic children showed different errors of reading (Visual-perceptual errors and Semantic errors). In the present study, The mean IQ of dyslexic patients (mean IQ = 101) was lower than that of normal controls (mean IQ = 117) However the result was of no statistical significance ($p>0.05$). The low IQ in dyslexic children could be explained by the impairment of phonological and visual processing as well as attention, and information processing speed. The results of IQ subtests in the present study showed a significant low value of visual reasoning as compared to normal controls. As regard language skills, 84% of dyslexic cases in the present study showed expressive language difficulties especially fluency ($p<0.05$). Similarly, Children with dyslexia also showed a significant lower result in fine and gross motor skills as compared to normal control children ($p<0.05$). As regard EEG in the present study, 17 Cases (85%) showed normal findings. Quantitative analysis of the EEG in the frequency domain has been shown to discriminate better normal and dyslexic children. A possible relation between these findings and delay cerebral maturation of dyslexic children was detected. **(Int. J. Ch. Neuropsychiatry, 2005, 2(2): 155-162)**

INTRODUCTION

Dyslexia, a specific reading disability, is the most frequent learning disability[1] with a prevalence ranging from 5-15% of school-age children[2]. It is reasonable to assume that at least one child in every classroom will experience significant difficulty to read.[3]

The exact etiology of dyslexia, as well as specific sensory deficits in dyslexia, remain controversial. Dyslexia was found to be a multifactorial outcome of deficits in phonological, neurological, visual, verbal, or genetic factors.[4] Dyslexia is likely secondary to deficits in brain. One would therefore expect that there are multiple points within the brain where dysfunction may lead to dyslexia.

Aim of the work:
The aim of this study was to:

1- assess the intellectual functions and the neuropsychological profile of a dyslexic children, and
2- evaluate routine EEG and EEG power density in brain regions for suggesting the possible factors at the cerebral level that might contribute to the problem of dyslexia.

MATERIALS AND METHODS

20 dyslexic (10 males and 10 females) and 20 non-dyslexic (control's) (10 males and 10 females) were chosen. The dyslexic children showed difficulty in recognition and recall of letters and the order of letters in words. The problem in school was so severe that children were referred to our neurology clinic in Alshatby hospital. Selection of dyslexic cases was according to DSM IV definition[5] " reading achievement is below the expected level for the child's age, education, and intelligence, and the impairment significantly interferes with academic success or the daily activities that involve reading". The chosen children were divided into 3 age groups (7-8, 8-9 and 9-10 year - old). They were subjected to testing of their ability to read and write using the dyslexic screening test (DST)[6]. The normal children were selected, as much as possible, at random from different schools. A part from dyslexic symptoms the difference between the two main studied groups (dyslexic and control) was kept at a minimum as far as possible.

All included children were subjected to the following:

1. Full medical history and clinical examination with special emphasis on CNS examination.
2. A battery of tests was used with the aim of covering different aspects of intellectual & neuropsychological assessment of the studied cases.
   The tests used were:
   a. IQ: using St Binnet test version 4 (Arabic version).
   b. Portage Assessment Program (PAP):[7]
      There were a number of basic areas of skills' assessment for evaluation, including: total skills, cognitive skill, fine motor skill, gross motor skill, receptive language skill, expressive language skill, social skill and self dependent skill. Data in this area was scored & recorded in the form of:
      - Total developmental age
      - Total rate of performance
      - Specific developmental age of each skill
      - Specific rate of performance of each skill
   c. Normal attention: after application of school form of children's attention and adjustment survey.[8]
3. Visual acuity and hearing assessment:
   a. Each case was referred to ophthalmologist to be submitted for visual acuity.
   b. All studied cases were assessed by audiologist for hearing assessment including audiometry and tympanometry
4. Reading assessment:
   a. dyslexia screening test – DST(6): this individually administered , standardized screener identifies children with signs of dyslexia. Reading, writing and spelling were examined in addition to precursor skills such as phonological awareness and fluency.
   b. Reading in relation to the educational level of the studied cases. It was based on a randomly chosen 3 paragraphs from the child's curriculum. We recorded the different errors (e.g., making up a story based on the book's illustration with no relation to the text, following text with his finger, reversal or rotation of letters or words, mispronouncing words, putting letters in the wrong words, misreading initial consonants, putting syllables in the wrong order of reading, misreading words of similar visual appearance regardless of meaning, omitting or reading twice little words alike).

5. Writing assessment:
   The writing problem is referred to by (dysgraphia). The same was done as in reading assessment but we randomly selected one paragraph (or a number of words).
6. Arithmetic assessment:
   The arithmetic problem is referred to by (dyscalculia). We tested three arithmetic processes:
   a. Basic counting
   b. Multi-digit addition or subtraction
   c. Word problem
7. EEG study using digital EEG machine – GALILO – SIRUS W.R:
   Including:
   a. Routine awake 10 minutes digital EEG recording
   b. EEG power density spectra in eight different regions (frontal, central, centroparietal, parieto-occipital, temprotempral).

Using Fast Fourier Transform (FFT) technique, an epoch of 10 seconds, free from artifacts and paroxysmal abnormalities, was chosen from the awaked record for analysis. A referential montage was selected. The basic EEG waves were defined as follows : delta (0.5 – 4 Hz), theta (4.5-8 Hz) , alpha (8.5-12 Hz), and beta (≥ 12.5 Hz). These waves were analyzed with regard to their absolute power frequency in all channels. This spectral analysis was represented in tables. The resultant data were statistically analyzed and compared between studied cases for the different EEG frequencies in the main areas: frontal, central, parietal, temporal, and occipital.

RESULTS

The age of dyslexic children in the present study ranged between 7-10 years with a mean of 7.5±1.73 years, while the age of controls ranged between 7-10 years with a mean of 7.3±1.23.

Table (1) showed the number of cases at different age groups. The number of cases at age group 7-8 were the highest (15 cases, 75%)

Table (2) showed the different reading and writing errors reported in the studied cases.

Table 3 showed the mean IQ score and IQ subtests of dyslexic child according to Stanford Binnet intelligence scale for children. Though the mean IQ of dyslexic children (mean IQ = 101) was lower than in controls (mean IQ=117), no statistical significance was detected between both ($p>0.05$). However, IQ subtests showed a statistical significant value between mean visual reasoning of dyslexic child and controls ($p<0.05$)

The results of skills assessment are shown in table (4). Total skills performance, motor (fine and gross), and language (receptive and expressive) skills were significantly lower in dyslexic children ($p<0.05$). Meanwhile, social and self –help skills and social IQ showed comparable levels with controls ($p>0.05$)

12 cases of dyslexic children (60%) showed reactive anxiety, 3 cases showed ADD (15%) and 2 cases (10%) showed reactive depression mixed with anxiety.

In trial to study quantitative analysis of the EEG. It showed that in the dyslexia children of aged 8 year – old group there were statistical differences in the spectra in the centro-occipital regions in the 10 & 11 Hz bands (Table 5). The power at these frequencies was statistically lower in dyslexic cases than in normal control cases. At the age of 9 years, these differences were no longer found. Whereas a significant difference in the 8-11 Hz band in the fronto-central regions, where in the normal control cases a higher power level were verified (Table 6). In the 10-year-old group (Table 7). Another difference was detected; a significant power increase in the dyslexic group for theta frequencies in the temporal regions.

Table 1. Distribution of studied cases (dyslexics and controls) according to age.

Age in years	Dyslexic cases		Controls	
7 – 8	15	75	11	55
>8 – 9	3	15	5	25
>9 - 10	2	10	4	20

Table 2. Reading and writing errors in the studied dyslexic cases.

Reading Errors (20 cases)	Number	Writing Errors (6 cases)	Number
1- read very slowly and hesitancy	15	1- Large sized and deformed letters	6
2- not related to text	7	2- write letters in the wrong orders	2
3- put letters in the wrong orders	6	3- mirror wrote words	3
4- misreads words of similar visual appearance	8	4- omits letters	3
5- follows text with his fingers	4	5- can't write words	6
6- constantly loses place			

Table 3. The results of IQ test.

	IQ	Auditory reasoning	Visual reasoning	Perceptual reasoning	Short memory
Dyslexic					
Mean	100.55	107.95	82.3*	103.5	103.4
Range	119-93	126-90	96-70	118-76	120-88
Control					
Mean	117.55	118.75	107	115.1	110.55
Range	140-101	132-101	164-70	140-84	132-78

* Statistically significant ($p<0.05$)

Table 4. The results of skills' assessment.

	total	cognitive	Fine motor	Gross motor	Receptive language	Expressive language	Self-help	Social
Dyslexic								
Mean	88.95*	86.35	91.7*	88.2*	94.45	84.8	86	86
Range	100-62	102-56	105-56	105-64	107-80	105-40	103-69	103-69
Control								
Mean	108.45	111.9	99.05	102.4	108.85	106.5	127.3	127.6
Range	124-96	128-94	122-81	118-90	123-95	122-95	169-94	169-94

* Statistically significant ($p<0.05$)

Table 5. EEG power spectra for the 8-year-old group: P values in various frequency bands and derivations.

Feq (Hz)	F – C		C – P		P – O		T – T	
	left	**right**	**left**	**right**	**left**	**right**	**left**	**right**
1 -<4	-	-	-	-	-	-	-	-
4 - 8	-	-	-	-	-	-	-	-
9	0.07	0.09	-	-	-	0.09	-	-
10	-	-	< 0.01	< 0.01	< 0.01	< 0.01	0.01	0.01
11	-	-	-	0.06	0.03	0.02	0.07	0.01
12	-	-	-	0.05	-	-	-	-
> 12	-	-	-	-	-	-	-	-

N.B.: p value above 0.10 are denoted by –.

Table 6. EEG power spectra for the 9-year-old group: P values in various frequency bands and derivations.

Feq (Hz)	F – C		C – P		P – O		T – T	
	left	**right**	**left**	**right**	**left**	**right**	**left**	**right**
1 -<4	-	-	-	-	-	-	-	-
4 - 7	-	-	-	-	-	-	-	-
8	0.06	0.09	0.09	-	-	-	-	-
9	0.05	0.05	-	-	-	-	-	-
10	<0.01	<0.01	-	-	-	-	-	-
11	0.04	<0.01	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-
> 12	-	-	-	-	0.10	-	-	-

N.B.: p value above 0.10 are denoted by –.

Table 7. EEG power spectra for the 10-year-old group: P values in various frequency bands and derivations.

Feq (Hz)	F – C		C – P		P – O		T – T	
	left	**right**	**left**	**right**	**left**	**right**	**left**	**right**
1 -<4	-	-	-	-	0.05	0.04	0.02	-
4	-	-	-	-	-	0.06	0.02	0.06
5	-	-	-	-	-	0.08	0.02	0.07
6	-	-	-	-	-	-	0.05	-
7	-	-	-	-	-	-	-	-
8-12	-	-	-	-	-	-	-	-
> 12	-	-	-	-	-	-	-	-

N.B.: p value above 0.10 are denoted by –.

DISCUSSION

In the present study, dyslexic children had a mean age of 7.5±1.73 years with highest percentage (50%) at the age group of 8 years. Our result is similar to other previous studies[9] as failure of scholastic achievement was almost the first sign for referral. In our study dyslexic children showed different errors of reading which can be subdivided into 2 main groups:

1. Visual-perceptual errors: manifested as reversal or rotation of letters, or large sized/ deformed letters.
2. Semantic errors: manifested mainly as skipping lines during reading, addition, and/or omission of part of words.

In the "balance" model developed by Bakker[10,11], it is suggested that beginning reading is characterized by an emphasis on visual-perceptual processing of letters which is mastered by the right hemisphere while advanced reading is characterized by an emphasis as semantic abstraction of the test which is mastered by the left hemisphere. This raises the importance of emphasis on hemisphere specific treatment of dyslexia subtypes.[12] It is now clear that the majority (not all) cases of dyslexia are attributable to a deficit in the processing of phonology, that is, the auditory code of language. Dyslexic individuals do not hear subtle differences between certain speech sounds, have trouble sequencing speech sounds appropriately, and consequently have difficulty with such tasks as breaking down words into syllables, rhyming, alliteration, and mapping speech sounds onto the visual symbols of written language. In this sense most dyslexic individuals have a "central auditory processing deficit," that is a deficit that cannot be attributed to malfunction of the ear. Determining precisely at what level of the relays of the central (subcortical/cortical) auditory pathway the dysfunction arises is still under investigation.

Dyslexia is unexpected underachievement in reading for one's intellectual ability[5]. In previous studies[7,12] and our present study, there was a difference in mean IQ in dyslexic patients as compared with normal non dyslexic children. However, mean IQ in dyslexic children in the present study was lower than in normal children. The low mean IQ in dyslexic children could be explained by the impairment of phonological and visual processing as well as attention span, and information processing speed[13]. The difficulties in attention and concentration observed in our dyslexic children mainly in tests of repetition of digits or phrases and histories, is fundamental in the art of read. The slowness in the performance of tasks, observed in several tests during IQ assessment (oral reading of text, writing of words) and distractibility, are indicative signs of dyslexia. The results of IQ subtests in the present study showed a significant low value of visual reasoning as compared to normal controls ($p<0.05$). Visual performance defect noticed in our dyslexic children could explain problems in spelling and formula[12]. The absence of sensory deficit (visual, or auditory), established in our study by the ophthalmologist and by the audiologist, was fundamental to exclude change in the receptive regions with dyslexia. Vicari et al.[13], stated that dyslexic children showed a reduced learning rate in the implicit but not in the declarative task suggesting a specific deficit of implicit learning. However, implicit learning is a cognitive function primarily processed by the cerebellum and so recent neurological and physiological data suggest a cerebellar dysfunction in dyslexia. Therefore, dyslexics' difficulties come from fundamental disorder in the brain which causes the input information not to be processed or stored in a conventional, generally linear fashion[14]. Thus the dyslexic children showed discrepancy between reading achievement and intelligence.

As regard language skills, in the present study 84% of dyslexic cases showed language difficulties. Expressive language skill, especially verbal fluency, was mainly affected. Dran and Natin[15] found high rates of reading problems among 63 preschool children with language difficulties. Barkley[16] reported that 60 % of children with reading difficulties had associated language disorder. Accordingly, trying to improve

children language skills especially expressive skills might lead to significant advantages in reading and spelling. A number of prospective and retrospective studies showed that children with early onset speech and language delay have great difficulty in learning to read.[17] Accordingly we can suggest that if a child shows delayed language development, has difficulty pronouncing words, has slow vocabulary growth or trouble finding the right word, this child should be considered to be at risk of dyslexia and should be referred for further language assessment and intervention[18] whereas specific remediation techniques for children with language disorders may prevent or minimize the risk that these children might develop later on dyslexia.[19]

Children with dyslexia also showed a lower result in fine and gross motor skills as compared to normal control children. Similarly, Viholaimer et al (2002) found a significant difference between dyslexic families and motor development (fine and gross)[20]. Hand writing disorders (dysgraphia) are felt to be secondary to deficits in fine motor skills. In the present study , there were 6 cases (37.5%) with dysgraphia. All of them showed language deficits (receptive and expressive) or comprehensive deficits. Other studies[21] showed that writing disorders to be related primarily to language disturbances and the remediation of language disorder is essential for treatment.[22]

EEG in the 85% (17 Cases) in the present study showed normal findings, similarly EEG in the majority of previous studied showed that dyslexic children had no abnormal epileptiform activity[23]. As regard quantitative analysis of the EEG in the frequency domain has been shown to discriminate better normal and dyslexic children. Sklar et al.[4] stated that, when the EEG of dyslexic children studied, they appeared to have some prominent differences, most commonly higher power in the theta activity. In our group we also found a higher power in the theta band in temporal region, but only for the children between 10 and 11 years. We analyzed the difference between the EEG spectra in dyslexic children and normal children in distinct age classes. The youngest group (8 years) the normal children showed a significantly higher power in the alpha band (9 to 11 Hz) this possibly related to the fact the psychomotor development of these children is more advanced than in dyslexics[1]. The fact that in the group of 9 –year– old children, the normal children showed higher power in the 8 – Hz band in the fronto-central region might be due to a higher amount of mu rhythm in the population. This means that sensorimotor area shows in the normal children a different activity from the dyslexics, which is presumably due to better development in normal children. In the eldest group (10 years) the power in the theta band in the dyslexics is higher than in the normal control children, due to a relative reduction of power in the theta band in normal control. This mean that there are age related differences between the power spectra of normal and dyslexic children, differences that suggest delayed cerebral maturation in the dyslexic children. Most of dyslexics (14 of 20) in the present study had symmetry of the different EEG waves between both hemisphere ($p>0.1$). In conclusion, the brains of individuals with dyslexia are organized somewhat differently and appear to process the phonological information in a less efficient, more diffuse manner.

Conclusion:

In a group of dyslexic children :

1. IQ showed no significant differences as compared with controls.
2. Visual reasoning is significantly defective in dyslexic children inspite of absence of sensory visual deficient which might be of diagnostic and treatment value
3. Expressive Language skills, especially fluency, and motor skills seemed to be affected in dyslexic children which might be of diagnostic and treatment value
4. If a child shows “speech delay”, has difficulty pronouncing words, has slow vocabulary growth or trouble finding the right word should be considered to be at risk for dyslexia

5. As regard age group and the power density of spectra of the EEG in eight different regions of the brain were compared with that of normal children in the same age:
   a) in the 8 – year old group the power in the alpha band was higher in the normals
   b) in the 9-year group we found a higher power of the mu rhythm in normals
   c) In the 10-year age the power in the temporal theta band was lower in normals A possible relation between these findings and delay cerebral maturation of dyslexic children.

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