Psychomotor function in children with epilepsy seen at a tertiary hospital in southern Nigeria: does treatment with anti-epileptic drugs have any effect?

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Abstract

Background: Psychomotor slowing is more commonly reported in children with epilepsy (CWE) compared to healthy controls. The effect of anti-epileptic drug (AED) treatment on psychomotor abilities of CWE remains controversial. In Nigeria, psychomotor abilities of CWE are scarcely investigated and the impact of AEDs is not known. The present study sought to assess psychomotor performance of CWE compared to healthy controls and to determine any association with seizure characteristics and treatment.

Method: A comparative cross-sectional study involving 160 children with idiopathic epilepsy and 80 controls aged 6–16 years. Psychomotor function was assessed using reaction times and tapping task of the Iron psychology computerised test battery. The criterion for impairment was fixed at two standard deviations (SD) worse than the mean of age-matched controls. The relationship between seizure variables and psychomotor function was assessed with the one-way analysis of variance (ANOVA).

Result: Fifty-nine (36.9%) CWE had impaired auditory reaction, 50 (31.3%) with impaired visual reaction and 11 (6.9%) had fine motor control impairment. There was no significant difference in psychomotor performance between CWE on AED and the newly diagnosed counterparts yet to start AED treatment (auditory reaction time—\(p = 0.226\); visual reaction time—\(p = 0.349\); tapping task—\(p = 0.818\)). AED treatment duration over 5 years was associated with better auditory reaction time (\(F = 4.631, p = 0.034\)) in CWE. Also, seizure onset before 5 years of age was associated with slower auditory reaction (\(F = 4.912, p = 0.028\)) and verbal reaction (\(F = 14.560, p < 0.001\)).

Conclusion: Nigerian CWE perform less favourably on tests of psychomotor function than healthy controls. The performance of children on AED is not significantly different from those not on AED. Longer duration of AED treatment may result in psychomotor improvement in CWE. CWE should be closely monitored for psychomotor slowness so that deficits can be identified and appropriate interventions instituted.

Keywords: Psychomotor function, Children with epilepsy, CWE, Auditory reaction, Visual reaction, Hand dexterity, Tapping task, Anti-epileptic drug, AED, Cognition

Background

Psychomotor ability refers to the capacity to perform physical motor movements with precision, coordination and strength [1]. They involve a combination of precise stimulus perception, processing and motor response. In...
a fast-paced world where academic and non-academic activities are time bound, limitation of psychomotor functions have far-reaching effect in children. Impaired psychomotor function can impact negatively on learning, school performance and psychosocial interactions [2]. Murrhy et al. [3] in a study of 133 children aged 8–12 years, showed that psychomotor ability significantly affected learning outcomes—reading and mathematics achievements, through its effect on short-term memory.

Psychomotor slowing is more commonly reported in children with epilepsy (CWE) compared to healthy controls [4–6]. Boelen et al. [4] in Netherland (2007) found statistically significant slowing in newly diagnosed children with idiopathic epilepsy compared to healthy controls using the Iron Psychology computerised test battery. In terms of magnitude of the effects, the difference in prevalence of psychomotor slowing between CWE and healthy controls was 12% for auditory reaction and 18% for visual reaction [4]. The prevalence of impaired hand dexterity, however, was comparable with controls. Reijs et al. [5] also found psychomotor impairment in 35.8% of children with cryptogenic lateralisation related epilepsy (CLRE) compared to 21.9% of healthy controls using the Movement Assessment Battery for Children (mABC). Other authors have reported significantly slower reaction times in CWE compared to healthy controls [6]. In spite of reported high prevalence, psychomotor slowing is usually understudied and undiagnosed in CWE [7]. Its impact on the quality of life and contribution to their morbidity is therefore, not fully understood.

The effect of anti-epileptic drug (AED) treatment on psychomotor abilities of CWE remains controversial. It is generally believed that psychomotor speed and fine motor coordination is the domain most commonly affected by AEDs [2, 8]. Although this position has been supported by studies involving adults with epilepsy [9, 10], the findings in children have been unconvincing. For example, Rathouz and colleagues [6] in a 6-year longitudinal study of 69 CWE found that psychomotor speed abnormality detected at or near the time of epilepsy diagnosis largely remained unchanged without evidence of progressive worsening or recovery. Similar conclusion was made by Garcia-Ramos and colleagues [7] in a 2-year longitudinal study involving 78 American children with idiopathic epilepsy. The observations suggest that AEDs might not have significant modifying effect on psychomotor performance of CWE. This view challenges the generally held opinion that the domain of cognition most closely affected by AED was psychomotor speed. Perhaps with more research, better insight will be gained into the effect of AED on psychomotor function in CWE.

In developing countries like Nigeria, psychomotor abilities of CWE are scarcely investigated. A few works on cognitive performance in Nigerian CWE have focused on intelligence [11] and academic performance [12, 13]. Furthermore, unrecognised psychomotor problems in CWE may negatively impact on their capacity to engage in timed task and ultimately their self-esteem. Early recognition and management is thus mandatory in clinical practice. The present study therefore sought to assess psychomotor performance of CWE compared to healthy controls. We hypothesised the following: (a) CWE will perform more slowly than healthy control in all tasks; (b) impairment would be worse in CWE on AED treatment than the newly diagnosed group.

**Methods**

**Study design**

We conducted a comparative cross-sectional study of children with epilepsy (CWE) recruited from the Pediatric Neurology Clinic and General Practice Clinic of a tertiary hospital in southern Nigeria. A total of 240 research participants were recruited for the study including 80 newly diagnosed CWE, 80 CWE on anti-epileptic drugs (AEDs) and 80 healthy controls. Selection criteria for CWE include (a) chronological age 6–16 years; (b) idiopathic epilepsy; (c) no other neurologic or psychiatric disorder. Idiopathic epilepsy was defined as epilepsy of unknown etiology and not due to somatic, neurologic or psychiatric disorder. The socio-economic class of study subjects and controls were classified into the high, middle and low socio-economic class based on the fathers’ profession and mothers’ level of education according to the method described by Olusanya et al. [14]. The controls were children without epilepsy attending the general practice clinic for medical examinations for school entry and placement as well as those presenting for follow-up visit after brief illnesses within the study period. Selection criteria for controls included: (a) chronological age 6–16 years, (b) no current neurologic or psychiatric disorder. The socio-economic class of study subjects and controls were classified into the high, middle and low socio-economic class based on the fathers’ profession and mothers’ level of education according to the method described by Olusanya et al. [15]. Patients were examined by a qualified medical doctor who documented all the findings.

**Assessment of psychomotor function**

The measures for psychomotor speed were assessed with the Iron Psychology (Fepsy) computerised test battery. Participants completed three motor tasks including auditory reaction time, visual reaction time and tapping task. Simple reaction times were measured using auditory stimuli (loud 800-Hz tone) and visual stimuli (white square on the screen) presented at random intervals by the computer. The test score is measured in milliseconds. The time to complete each task was recorded and used as the dependent variable in all analyses. The finger-tapping task (a measure of hand dexterity and fine motor control) required the participant to tap as fast as possible using
the index finger of the dominant hand. The participant was given five consecutive trials. The average number of tapping in a 10-s trial was recorded.

Data analysis
The collected data were organised, tabulated and statistically analysed using the Statistical Package for Social Sciences (Version 21.0; IBM SPSS statistics, Chicago, IL, 2011). The auditory reaction times, visual reaction times and the average number of tapping were summarised as mean ± standard deviation (SD) and compared using the Student’s t-test. The times were further dichotomised into impaired and normal. The criterion for impairment on the tasks was fixed at two standard deviations (SD) worse than the mean of age-matched controls. One-way analysis of variance (ANOVA) was used to assess the relationship between seizure variables (age at seizure onset, duration of epilepsy, type of seizure and seizure frequency) treatment variables (duration of treatment and number of AEDs) and psychomotor function. Chi-squared tests were used to analyse differences in prevalence of impairment. Differences were considered to be statistically significant if their two-tailed p-values were less than 0.05.

Results
The demographic and clinical characteristics of the CWE and controls are presented in Table 1. CWE had slower auditory and visual reaction times than control, but significantly better hand dexterity than controls (Table 2). CWE on AED did not significantly differ from the newly diagnosed counterparts yet to start AED treatment (Table 3). Fifty-nine (36.9%) CWE had impaired auditory reaction, 50 (31.3%) with impaired visual reaction and 11 (6.9%) had fine motor control impairment. Among the controls, four children (5.0%) had auditory reaction impairment; three (3.8%) had visual reaction impairment and eight (10%) had impaired tapping task (Fig. 1). The prevalence of psychomotor impairment in CWE was significantly higher than the controls on test of auditory reaction ($\chi^2 = 33.900; p < 0.001$) and visual reaction ($\chi^2 = 23.441; p < 0.001$), but not on fine motor control (finger tapping task) function ($\chi^2 = 0.08; p = 0.779$). Longer duration of treatment [$F(1,156) 4.631, p = 0.0341$] was only significantly associated with better auditory reaction time task. Earlier age at onset of seizure was significantly associated with poorer auditory reaction [$F(1,156) 4.912, p = 0.028$] and verbal reaction [$F(1,156) 14.56, p < 0.001$] (Table 4).

| Table 1 | Demographic and clinical characteristics of study population |
|---------|-------------------------------------------------------------|
|          | CWE          | Controls                  |
| Age (mean ± SD) | 10.65 ± 2.90 | 11.01 ± 2.61 |
| Sex        | Male 81 (50.6%) | 41 (51.3) |
|           | Female 79 (49.4%) | 39 (48.7) |
| Socio-economic class | Upper 68 (42.5) | 62 (77.5) |
|           | Middle 44 (27.5) | 13 (16.3) |
|           | Lower 48 (30.0) | 5 (6.2) |
| Age of epilepsy onset | < 5 years 74 (46.3) | > 5 years 86 (55.7) |
| Type of seizure | Focal 35 (21.9) | Generalised 125 (78.1) |
| Duration of epilepsy | < 5 years 105 (65.6) | ≥ 5 years 55 (34.4) |
| Seizure frequency | > 1/month 46 (28.8) | < 1/month 87 (54.4) |
|             | Yearly/none in 2 years 27 (16.8) |
| Duration of treatment | < 5 years 67 (83.8) | > 5 years 13 (16.2) |
| Number of AEDs | Monotherapy 71 (88.8) | Polytherapy 9 (11.2) |

| Table 2 | Psychomotor performance of children with epilepsy and controls |
|---------|---------------------------------------------------------------|
| Test (dominant hand) | CWE          | Controls                  | F    | p     |
| Auditory reaction timeα | 493.3 (156.5) | 393.0 (80.6) | 28.983 | <0.001* |
| Visual reaction timeα | 474.0 (143.7) | 364.1 (96.5) | 38.118 | <0.001* |
| Tapping taskβ | 49.2 (8.0) | 45.2 (19.4) | 4.987 | 0.026* |

*Significant at p < 0.05; α—lower values indicate better performance; β—higher values indicate better performance

| Table 3 | Psychomotor function in CWE on AED treatment and CWE yet to commence treatment |
|---------|---------------------------------------------------------------|
| Test (dominant hand) | AED treatment | No treatment | F    | p     |
| Auditory reaction timeα | 478 (138) | 508 (173) | 1.476 | 0.226 |
| Visual reaction timeα | 463 (136) | 484 (151) | 0.882 | 0.349 |
| Tapping taskβ | 49.1 (9.2) | 49.3 (6.7) | 0.053 | 0.818 |

α—lower values indicate better performance; β—higher values indicate better performance
Discussion

Our findings indicate that children with epilepsy had slower auditory and visual reaction times, but significantly better finger tapping speed than controls. There was no significant difference in psychomotor performance between CWE on AED and the newly diagnosed counterparts yet to start AED treatment. Duration of treatment beyond 5 years was associated with better auditory reaction time. Seizure onset before 5 years of age was associated with better psychomotor function.

| Characteristics | Auditory reaction<sup>a</sup> | Visual reaction<sup>a</sup> | Tapping Task<sup>b</sup> |
|----------------|-----------------------------|-----------------------------|-------------------------|
|                | Duration (SD) | F  | p     | Duration (SD) | F  | p     | Duration (SD) | F  | p     |
| Age at epilepsy onset |               |    |       |               |    |       |               |    |       |
| < 5 years | 523 (171) | 4.912 | 0.028* | 519 (159) | 14.560 | <0.001* | 48.49 | 1.028 | 0.312 |
| ≥ 5 years | 469 (139) |        |       | 435 (117) |        |       | 49.78 |        |       |
| Duration of epilepsy |               |    |       |               |    |       |               |    |       |
| ≤ 5 years | 501 (152) | 0.790 | 0.375 | 483 (149) | 1.195 | 0.276 | 48.54 | 2.031 | 0.156 |
| > 5 years | 478 (164) |        |       | 456 (132) |        |       | 50.44 |        |       |
| Type of seizure |               |    |       |               |    |       |               |    |       |
| Focal | 536 (220) | 3.401 | 0.067 | 472 (30) | 0.007 | 0.932 | 49.67 | 0.157 | 0.693 |
| Generalised | 481 (132) |        |       | 475 (12) |        |       | 49.06 |        |       |
| Seizure frequency |               |    |       |               |    |       |               |    |       |
| 0–1 in 2 years | 481 (126) | 0.098 | 0.906 | 440 (117) | 1.026 | 0.361 | 50.99 | 1.367 | 0.258 |
| ≤ 1 seizure/month | 495 (177) |        |       | 476 (157) |        |       | 49.36 |        |       |
| > 1 seizure/month | 495 (130) |        |       | 489 (129) |        |       | 47.83 |        |       |
| Duration of treatment |               |    |       |               |    |       |               |    |       |
| < 5 years | 497 (144) | 4.631 | 0.0341* | 477 (145) | 2.335 | 0.131 | 47.96 | 3.244 | 0.076 |
| ≥ 5 years | 424 (97) |        |       | 424 (99) |        |       | 52.10 |        |       |
| Number of AEDs |               |    |       |               |    |       |               |    |       |
| Monotherapy | 478 (142) | 0.002 | 0.960 | 460 (137) | 0.305 | 0.583 | 49.01 | 0.010 | 0.922 |
| Polytherapy | 480 (85) |        |       | 487 (125) |        |       | 49.33 |        |       |

<sup>a</sup>Significant at p < 0.05; α—lower values indicate better performance; β—higher values indicate better performance.
age was associated with poor auditory reaction and verbal reaction. In the current study, CWE performed significantly worse than controls on measures of auditory and visual reaction. This finding agrees with the conclusion of Rathouz et al. [6] and Boelen et al. [4] showing longer reaction time in CWE, compared to controls. Slower reaction in CWE may be attributed to general cerebral inhibition and disruption of neural transmission by the epileptic seizure as well as the effect of anti-epileptic medications. Psychomotor impairment has also been demonstrated in newly diagnosed children around or before onset of seizure [7]. Thus psychomotor slowing in CWE might be a marker for abnormal brain development rather than the effect of seizures themselves.

An interesting observation in the present study was that finger tapping speed, a measure of hand dexterity and fine motor control, was higher in CWE compared to controls. Boelen et al. [4] also observed better fine motor control among CWE compared with control group. They, however, considered it a chance effect. It is likely that the better performance by CWE is behavioural. Tanner and colleagues have shown that intentional sub-optimal performance of tapping task can be simulated by persons motivated to perform less than optimally [16]. It may also be true that people who were more motivated to perform optimally will tap faster than those who were not. Children with epilepsy might have been more enthusiastic about the test being a part of their management than were controls. Henkin et al. [17] however, reported worse finger tapping in CWE compared to healthy controls. The reason for the difference in the current study is not clear. This observation, however, may need further investigation and possibly a prospective approach.

Anti-epileptic drug treatment may not significantly impair psychomotor function as previously suggested [8, 18–21]. In the present study, the performance of children on AED was not significantly different from the result of their counterparts who were recently diagnosed and not on AED treatment on all tests. This observation is in agreement with the findings of Boelen et al. [4] among 87 Dutch children with uncomplicated epilepsy. They observed that AEDs drug load (defined as the ratio of prescribed daily dose to defined daily dose) did not significantly affect psychomotor function in CWE. Similarly, Rathouz et al. [6] in a 6-year prospective study of 69 children with epilepsy reported that the psychomotor impairment noted at the onset of seizures did not change with treatment at 6 years follow-up. Some studies assessing psychomotor performance of CWE following discontinuation of AEDs have reported significant improvement with re-testing [22, 23]. It is probable that the improvement in psychomotor performance was due to test–retest advantage (practice effect) rather than reversal of AED-induced psychomotor slowing.

In the current study, the duration of treatment appears to be associated with improved psychomotor performance. Children who have been on AED treatment for more than 5 years had a better profile for auditory reaction than those with lesser duration of treatment. Similar observations were made with respect to visual reaction and fine motor control although both were not statistically significant. Studies on the effect of AED treatment on psychomotor performance have been inconclusive. A few authors have however, reported improvement in psychomotor abilities following commencement of AED treatment [2, 7]. It is likely, that the improvement of psychomotor function is as a result of reduced disturbance from recurrent seizures.

In the present study, psychomotor slowing was more prominent in children whose seizure started before their fifth birthday compared to those whose seizure onset was later. While this is plausible, most studies of psychomotor function in children have not considered the influence of age of onset on psychomotor performance. Younger age at onset of epilepsy has been associated with poorer cognitive function in CWE [8, 24–26]. Epileptiform discharges at young age could disrupt brain circuits’ formation and negatively affect neurodevelopmental processes including synaptogenesis and apoptosis [26]. These interferences would ultimately result in slow impulse generation and transmission and commonly manifest as slow reaction times. Similarly, earlier seizure may suggest more severe neuronal injury and thus greater functional abnormality.

Conclusion
In conclusion, psychomotor slowing is common in Nigerian CWE. Children with epilepsy perform less favourably on tests of reaction time than healthy controls. The performance of children on AED is not significantly different from those not on AED. On the contrary, the present study suggests that AED treatment might improve psychomotor impairment in CWE. Care givers should monitor CWE closely for psychomotor slowness and other motor impairments. Early psychomotor assessment should be done so that deficits can be identified and appropriate interventions instituted.

Limitation of study
In terms of study limitations, the study utilised a hospital-based sample, thus, selection biases may have affected study inclusion and limit the generalisability of results to all children with epilepsy. Secondly, the use of cross-sectional design limits its ability to establish causality.
However, the results of this study provide evidence that psychomotor problems are common in CWE.

Abbreviations
CWE: Children with epilepsy; AED: Anti-epileptic drug; Fepsy: Iron psychology computerised test battery; CLRE: Cryptogenic lateralisation related epilepsy; mABC: Movement assessment battery for children; SD: Standard deviation; ANOVA: Analysis of variance.

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Authors’ contributions
PEI conceptualised the work and designed the study. He also participated in data collection, data analysis, interpretation of data as well as drafting of the article. He approved the final version to be published. OPO—study design, data collection, interpretation of data, revision of draft critically for important intellectual content; and final approval of the version to be published. BA—study design, data analysis and interpretation, drafting the article and final approval of the version to be published. GEO—conceptualisation and study design, interpretation of data, revision of draft critically for important intellectual content and final approval of the version to be published. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets 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 research was reviewed and approved by the University of Benin Teaching Hospital ethics and research committee (protocol number: ADIM/E22/A/ VOL.1457). Signed informed consent was obtained from participants’ parents after the nature and purpose of the test was explained to their understanding. Participation was completely voluntary and participant could withdraw at any time.

Consent for publication
Not applicable.

Competing interest
The authors declare that they have no competing interests.

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References
1. Flanagan DP, Dixon SG. The Cattell-Horn- Carroll Theory of cognitive abilities. In: Ceci RJ, Reynolds, Vannest KJ, Fletcher-Janzen E, eds. Encyclopedia of Special Education. Fourth. John Wiley & Sons, Inc., 2014.
2. Donat F, Gobbi G, Campistol J, et al. The cognitive effects of oxcarbazepine versus carbamazepine or valproate in newly diagnosed children with partial seizures. Seizure. 2007;16(8):670–9.
3. Murphy C, Bailey M, Roodenburg J. Psychomotor ability and short-term memory, and reading and mathematics achievement in children. Arch Clin Neuropsychol. 2017;32(5):618–30.
4. Boelen S, Nieuwenhuis S, Steenbeek L, et al. Effect of epilepsy on psychomotor function in children with uncomplicated epilepsy. Dev Med Child Neurol. 2007;49(8):546–50.
5. Reiss RP, De La Parra NM, Van Mil SG, et al. Motor function in children with cryptogenic localization related epilepsy. Seizure. 2010;19(8):467–9.
6. Rathouz PJ, Zhao Q, Jones JE, et al. Cognitive development in children with new onset epilepsy. Dev Med Child Neurol. 2014;56(7):635–41.
7. Garcia-Ramos C, Dabbs K, Meyerand E, et al. Psychomotor slowing is associated with anomalies in baseline and prospective large scale neural networks in youth with epilepsy. Neurolmage Clin. 2018;19:222–31.
8. Lodhi S, Agrawal N. Neurocognitive problems in epilepsy. Adv Psychiatr Treat. 2012;18(3):232–40.
9. Ogunrin O, Adamolekun B, Oguniyi A. Cognitive effects of anti-epileptic drugs in Nigerians with epilepsy. African J Neurol Sci. 2008,24(1):18–24.
10. Gupta M, Patel P, Gandhi A, Desai M. Effect of antiepileptic drugs on psychomotor functions and memory in epilepsy patients. J Young Pharm. 2017;9(3):557–61.
11. Lagunju OA, Adeniyi YC, Olukolade G. Cognitive function in Nigerian children with newly diagnosed epilepsy: a preliminary report. Pan Afr Med J. 2016;24:113.
12. Nuhu FT, Yusuf AJ, Sheikh TL, Eseigbe EE. Poor academic performance among adolescents with epilepsy in Kaduna, Northern Nigeria: a case-control study. South Afr J Child Health. 2012;6(4):132–4.
13. Ibekevu RC, Ojinnaka NC, Iioje SO. Factors influencing the academic performance of school children with epilepsy. J Trop Pediatr. 2007;53(5):338–43.
14. Berg AT, Berkovic SF, Brodie MJ, et al. Revised terminology and concepts for organization of seizures and epilepsy: report of the ILAE Commission on Classification and Terminology, 2005–2009. Epilepsia. 2010;51(4):676–85.
15. Olusanya O, Opper E, Ezimokhai M. The importance of social class in voluntary fertility control in a developing country. West Afr J Med. 1985;4:205–12.
16. Tanner B, Bowles R, Tanner E. Detection of intentional sub-optimal performance on computerised finger tapping task. J Clin Psychol. 2003;59(1):123–31.
17. Henkin Y, Sadeh M, Kivity S, Shabtai E, Kishon-Rabin L, Gadoth N. Cognitive function in idiopathic generalized epilepsy of childhood. Dev Med Child Neurol. 2005;47(2):126–32.
18. Sherman EMS, Brooks BL, Fay-mcclymont TB, Macallister WS. Detecting epilepsy-related cognitive problems in clinically referred children with epilepsy: is the WISC-IV a useful tool? Epilepsia. 2012;53(6):1060–6.
19. Hamid SA. The aspects and mechanisms of cognitive alterations in epilepsy: the role of antiepileptic medications. CNS Neurosci Ther. 2009;15(2):134–56.
20. Marsh ED, Brooks-Kayal AR, Porter BE. Seizures and antiepileptic drugs: does exposure alter normal brain development? Epilepsia. 2006;47(12):1999–2010.
21. You SJ. Cognitive function of idiopathic childhood epilepsy. Korean J Pediatr. 2012;55(5):159–63.
22. Aldenkamp AP, Alpherts W, Blenning G, et al. Withdrawal of antiepileptic medication in children—effects on cognitive function: the Multicenter Holmfrid Study. Neurology. 1993;43(1):41–50.
23. Van Schooneveld M, Van Erp N, Boshuizen K, Meekes J, Braun KP. Withdrawal of antiepileptic drugs improves psychomotor speed after childhood epilepsy surgery. Epilepsy Res. 2013;107(1–2):200–3.
24. Sánchez-Carpintero R, Neville BGR. Attentional ability in children with epilepsy: is the WISC-IV a useful tool? Epilepsia. 2003;44(10):1340–9.
25. Hermann BP, Jones JE, Jackson DC, Seidenberg M. Starting at the beginning: the neuropsychological status of children with new-onset epilepsies. Epileptic Disord. 2012;14(1):12–21.
26. Nihl E-H, Ko T-S. Cognitive impairment in childhood onset epilepsy: up-to-date information about its causes. Korean J Pediatr. 2016;59(4):155–64.

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