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Evaluation of auditory brainstem responses in individuals diagnosed with speech delay

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Abstract

Disruption of language skills at any stage of life can negatively affect an individual's psychosocial development, similar to other disability groups. In some cases, even if peripheral hearing is within normal limits, language development may still be delayed. This retrospective study included 104 children aged 12 to 72 months presenting with speech delay. The Turkish Early Language Development Test (TEDIL) was used to diagnose speech delay in children whose receptive and expressive language skills were below chronological age. Auditory Brainstem Response (ABR) testing was performed to record the latencies and amplitudes of waves I, III, and V. Absolute latencies and interpeak latencies (I–III, III–V, I–V) were statistically analyzed. Statistical analysis revealed significant differences in wave latencies of the right and left ears for children aged 15–24 months when compared to normative values ($p<0.05$). In children aged 25–36 months, both wave and interpeak latencies were significantly different from normative values ($p<0.05$). Similar significant differences were observed in children older than 36 months ($p<0.05$). However, no significant difference was found in wave I of the left ear and in the interpeak latencies between waves III–V in either ear ($p>0.05$). The study demonstrated latency delays in waves I, III, and V in individuals diagnosed with speech delay. These delays in auditory brainstem responses may be indicative of underlying cognitive processing deficits contributing to delayed language development.

Keywords: Auditory brainstem response, speech delay, language disorder, Turkish Early Language Development Test

Introduction

Language development has long been a subject of interest across various disciplines, from linguists and philosophers to physicians. Any disruption in language skills at any stage of life, similar to other types of disabilities, can negatively impact an individual's psychosocial existence and development. This situation can lead to more dramatic consequences, particularly in cases of childhood language disorders. Language disorders may stem from organic or non-organic causes. One subset of these disorders seen in childhood is Developmental Language Disorder (DLD). DLD refers to language difficulties that occur without any identifiable pathology or disability. It is also referred to in the literature as specific language impairment or primary language disorder [1]. Although prevalence rates vary, children presenting to pediatric neurology clinics with speech delay or disorders account for approximately 15% to 50% of cases [2]. Children with DLD typically fail to demonstrate receptive and expressive language skills appropriate for their age.

Developmental language disorders can arise from various factors. While neurobiological deficiencies, parental neglect, and a lack of environmental stimulation are noted as possible contributors, the most strongly associated factor is impairment in the auditory system [2,3]. In some cases, language development may be delayed even when the child's hearing is within normal

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limits. When language development disorders are observed in children with normal hearing and without comorbidities such as cerebral palsy or metabolic deficiencies, they are categorized as idiopathic DLD [2]. However, there is currently no specific neurophysiological test battery capable of definitively identifying the underlying cause of this condition [4].

Various assessment tools such as surveys, scales, and speech recordings may be used to evaluate language problems like DLD [5]. Although these tools help in identifying the status of a language disorder, they fail to provide information regarding lesion localization. Therefore, neurophysiological tests and radiological imaging are necessary. Auditory Brainstem Response (ABR) testing is a valuable electrophysiological diagnostic tool used in neurological evaluation. ABR provides information on the central auditory system, spanning from the cochlea to the inferior colliculus. As such, it is useful in assessing both auditory maturation and neurological disorders. ABR results are interpreted based on parameters such as intensity, morphology, and latency.

In individuals with normal hearing, responses are typically recorded within the first 5.5–6 milliseconds following a high-intensity stimulus of 70 dB nHL or higher. While latency remains constant at higher stimulus levels, amplitude continues to increase. Gender-related literature reports lower latency values in females. Regarding age, adults over 60 exhibit longer latency durations compared to younger adults. In children, the amplitude, morphology, and latency of ABR waves resemble those of adults after approximately 18 months of age.

Previous studies have shown impaired brainstem responses in preterm children and in preschool-aged children with attention deficit. The relationship between language development and ABR has also been examined in various age groups and in terms of both amplitude and latency [6]. Although some studies show a correlation, the results remain inconsistent. The aim of this study is to evaluate the latencies and amplitudes of auditory brainstem responses in children aged 12 to 72 months who are diagnosed with speech delay.

Material and Methods

This retrospective descriptive study included 104 children aged 12 to 72 months who were referred to the Department of Otorhinolaryngology at İnönü University Turgut Özal Medical Center between 2018 and 2024 due to complaints of delayed speech. Diagnosis of speech delay was established using the Turkish Early Language Development Test (TEDIL), identifying children whose receptive and expressive language skills were below their chronological age. Auditory Brainstem Response (ABR) testing was performed, and absolute latencies of waves I, III, and V, as well as interpeak latencies (I–III, III–V, I–V), were recorded and analyzed statistically. This study was carried out in accordance with the principles of the Declaration of Helsinki, after receiving approval from the ethics committee of İnönü University Faculty of Medicine (date: 03.01.2025/ number: 2025/6642)

Inclusion Criteria

- Age between 12 and 72 months,
- Diagnosed with speech delay,
- No history of language education,
- Absence of mental retardation or cognitive impairments,
- Bilateral positive otoacoustic emission (OAE) test results,
- Normal otoscopic examination findings,
- Bilateral normal middle ear findings in tympanometric assessment.

Exclusion Criteria

- Age outside the 12–72 month range,
- Presence of mental retardation,
- Presence of hearing loss,
- Abnormal otoscopic examination findings,
- Presence of middle ear pathology.

Assessments Conducted

TEDIL (Turkish Early Language Development Test): This is the Turkish adaptation of the Test of Early Language Development (TELD-3). TEDIL is a norm-referenced, individually administered test that evaluates children's receptive and expressive verbal language levels . It is used for early identification of language deficiencies, determining strengths and weaknesses in language development, obtaining information about developmental processes, and conducting research [7].

ABR TEST (Auditory Brainstem Response): All children included in the study had previously passed bilateral newborn hearing screenings. Otoscopic examination and immittance measurements were within normal limits, and all children had bilateral positive Transient Evoked Otoacoustic Emission (TEOAE) results. None of the children had additional diseases or neurological/metabolic disorders. Eight children who did not meet the inclusion criteria were excluded from the study.

Bilateral ABR assessments were performed for the children in the study group. ABR tests were conducted at the Audiology Clinic of the Department of Otorhinolaryngology, İnönü University Turgut Özal Medical Center, using a Nihon Kohden Neuropack 2 system and TDH-39 headphones. Threshold detection was performed by observing the presence of wave V down to 20 dB nHL. The test was initiated using an 80 dB nHL click stimulus with alternating polarity at a rate of 30. Absolute latencies of waves I, III, and V, and interpeak latencies of I–III, III–V, and I–V were recorded. Means were compared with normative data from the literature based on age groups (Table 1) [8].

Table 1. Normative values for absolute and interpeak latencies of ABR waves I, III, and V obtained at 80 dB nHL in children aged 0–6 years with normal hearing

Age range	Wave I	Wave III	Wave V	I–III	III–V	I–V
0–3 months (Mean)	1.84	4.62	6.77	2.77	2.14	4.92
Std. dev.	0.28	0.35	0.47	0.19	0.25	0.40
3–6 months (Mean)	1.47	4.09	6.39	2.62	2.30	4.92
Std. dev.	0.08	0.07	0.04	0.02	0.11	0.08
6 mo–1 yr (Mean)	1.60	4.32	6.34	2.72	2.01	4.73
Std. dev.	0.14	0.16	0.17	0.18	0.20	0.18
1–1.5 years (Mean)	1.68	3.88	5.79	2.20	1.88	4.08
Std. dev.	0.16	0.11	0.25	0.08	0.17	0.10
1.5–2 years (Mean)	1.51	3.84	5.91	2.32	2.06	4.38
Std. dev.	0.09	0.12	0.13	0.11	0.11	0.07
2–3 years (Mean)	1.43	3.69	5.53	2.09	2.03	4.13
Std. dev.	0.06	0.24	0.21	0.18	0.23	0.13
3–6 years (Mean)	1.58	3.68	5.56	2.14	1.98	3.79
Std. dev.	0.18	0.24	0.16	0.16	0.60	0.53

Statistical Analysis

Statistical analyses were performed using IBM SPSS 21 software. Mean, standard deviation, Wilcoxon test, and t-test were used for data analysis. The Shapiro-Wilk test was applied to assess the normal distribution of variables. Data were summarized using mean, minimum, and maximum values. For comparisons, Wilcoxon signed-rank tests and Friedman tests were utilized. Following the Friedman test, the Conover method was applied for multiple comparisons. A p-value of <0.05 was considered statistically significant in all tests.

Results

A total of 96 children were included in the study: 18 girls (18.8%) and 78 boys (81.2%). The distribution of participants by age group is shown in Table 2.

Table 2. Distribution of demographic characteristics of the participants

Age group (months)	Number of participants	Percentage (%)
15–24 months	16	16.6
25–36 months	40	41.7
37+ months	40	41.7
Total	96	100

According to the analysis, significant differences were found between the latencies of ABR waves I, III, and V in both right and left ears of children aged 15–24 months compared to normative values ($p<0.05$). However, no statistically significant differences were found in the interpeak latencies ($p>0.05$) (Table 3).

Table 3. Comparison of ABR wave latencies in right and left ears of children aged 15–24 months with normative values

Waves	Ear	N	Mean	p-value
Wave I	**Right ear**	16	1.6656	0.000
	Left ear	16	1.6556	0.000
Wave III	**Right ear**	16	4.0306	0.000
	Left ear	16	4.0069	0.001
Wave V	**Right ear**	16	6.0344	0.000
	Left ear	16	6.0000	0.000
I–III interval	**Right ear**	16	2.3650	0.120
	Left ear	16	2.3513	0.356
III–V interval	**Right ear**	16	2.0038	0.103
	Left ear	16	1.9931	0.062
I–V interval	**Right ear**	16	4.3687	0.810
	Left ear	16	4.3444	0.501

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In children aged 25–36 months, significant differences were found in both the absolute latencies of ABR waves I, III, and V and the interpeak latencies when compared with normative values ($p<0.05$) (Table 4).

Table 4. Comparison of ABR wave latencies in right and left ears of children aged 25–36 months with normative values

Waves	Ear	N	Mean	p-value
Wave I	**Right ear**	40	1.6645	0.000
	Left ear	40	1.6408	0.000
Wave III	**Right ear**	40	3.9610	0.000
	Left ear	40	3.9010	0.000
Wave V	**Right ear**	40	5.8805	0.000
	Left ear	40	5.8715	0.000
I–III interval	**Right ear**	39	2.2928	0.000
	Left ear	40	2.2998	0.000
III–V interval	**Right ear**	40	1.9195	0.000
	Left ear	40	1.9363	0.000
I–V interval	**Right ear**	40	4.2180	0.002
	Left ear	40	4.2360	0.000

In children older than 36 months, both the absolute latencies of ABR waves I, III, and V and the interpeak latencies in both ears showed statistically significant differences compared to normative values ($p<0.05$). However, no significant difference was found in wave I of the left ear and in the interpeak latency between waves III–V of either ear ($p>0.05$) (Table 5).

Table 5. Comparison of ABR wave latencies in right and left ears of children over 36 months with normative values

Waves	Ear	N	Mean	p-value
Wave I	**Right ear**	40	1.6373	0.002
	Left ear	40	1.6252	0.167
Wave III	**Right ear**	40	3.8898	0.000
	Left ear	40	3.8925	0.000
Wave V	**Right ear**	40	5.8510	0.000
	Left ear	40	5.8583	0.000
I–III interval	**Right ear**	40	2.2560	0.000
	Left ear	40	2.2673	0.000
III–V interval	**Right ear**	40	6.5650	0.325
	Left ear	40	1.9657	0.433
I–V interval	**Right ear**	40	4.2173	0.000
	Left ear	40	4.2330	0.000

Discussion

In this study, the findings of TEDIL and ABR tests in individuals who presented with complaints of delayed speech were evaluated. None of the children in the study exhibited any additional neurological findings. Statistical analyses were performed with respect to age and gender. One of the prerequisites for normal language development is a highly sensitive auditory perception. Therefore, a deficiency in auditory perception is likely to interfere with typical language acquisition.

A noteworthy study by Salamy and Mendelson (1980) compared the brainstem auditory evoked responses (BAER) of infants with perinatal complications to those of healthy infants during the first year of life. They found that in high-risk infants, waves I, III, and V were delayed; however, the latencies of waves I and V converged within the first five months. These findings suggest measurable differences in brainstem transmission that could potentially underlie or contribute to later neurological soft signs or cognitive disorders observed in such children [9].

Other studies have shown that children with speech and language disorders take longer to perceive and differentiate tonal or auditory stimuli compared to those with typical language development [10]. In children with central language disorders, auditory transmission deficits below the level of the olivary nucleus in the brainstem have been proposed [11-13]. Some researchers have argued that delayed or altered transmission of acoustic stimuli in waves III, IV, and V plays a significant role in the pathogenesis of developmental language disorders [14].

Although findings in the literature vary by gender, our study also showed a predominance of male participants (81.2% male vs. 18.8% female). In contrast to many previous studies that did not stratify ABR wave data by age in diagnosed individuals, our study divided children aged 0–6 into three distinct age groups. We aimed to assess whether ABR wave latencies varied with age.

Group analyses showed that in children aged 15–24 months, the latencies of ABR waves I, III, and V in both ears differed significantly from normative values ($p<0.05$), while no significant difference was observed in interpeak latencies ($p>0.05$). In children aged 25–36 months, both wave latencies and interpeak latencies differed significantly from normative data ($p<0.05$). Similarly, in children aged over 36 months, significant differences were found in both wave and interpeak latencies ($p<0.05$). However, wave I of the left ear and the interpeak latency between waves III and V showed no significant differences ($p>0.05$).

Previous studies indicating that maturational delays may manifest with cognitive and neurological consequences suggest that these findings could be linked to the delayed wave responses observed in our study [10]. In neurological disorders and conditions such as auditory neuropathy, ABR peaks may be diminished or absent due to desynchronized or prolonged conduction [15]. Another study reported that the latencies of all waves in speech ABR (sABR), as well as the duration of the V–A complex, were significantly longer in children with autism spectrum disorder compared to typically developing children [16].

Based on the evaluations in our study, delays were observed in waves I, III, and V of the auditory brainstem responses in individuals diagnosed with speech delay. These delays may represent a contributing factor to cognitive processing deficits and delayed language development.

Conclusion

One of the possible underlying causes of speech delay is thought to be maturational delay. The findings of this study suggest the importance of early identification of such maturational issues. In individuals presenting with complaints of delayed speech, the use of central auditory evaluations in diagnostic processes may help guide therapeutic interventions tailored to the presence of auditory maturation delays.

Moreover, conducting pre- and post-therapy assessments may provide a more effective framework for managing the therapeutic process. Future studies evaluating individuals before and after treatment may further contribute to the literature and clinical understanding.

Conflict of Interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

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Ethical Approval

This study was carried out in accordance with the principles of the Declaration of Helsinki, after receiving approval from the ethics committee of İnönü University Faculty of Medicine (date: 03.01.2025 / number: 2025/6642).

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