The Relationship between Nutritional Status and the Latency Period of Wave V of the BERA in Toddlers with Speech Disorders and Normal Hearing

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Abstract

The causes of speech disorders in children are multifactorial, one of which is nutritional status that affects the maturation of the auditory nervous system. Brainstem Evoked Response Audiometry (BERA) examination is used for early detection of speech disorders in children, by assessing the speed of conduction of auditory nerve impulses, and is sensitive to neurological maturation disorders, changes in wave V latency indicate delays in the development of the central auditory pathway. Objective: To determine the relationship between nutritional status and wave V latency of BERA in toddlers with speech disorders and normal hearing. Methods: Retrospective study using medical record data sources on all children with speech disorders and normal hearing at the ENT-BKL Polyclinic of RSUDZA Banda Aceh for the period January 2024-October 2025. Results: There were 60 samples, 17 children with speech disorders and normal hearing experienced malnutrition, 3 children with undernutrition, 27 children with normal nutritional status 6 children with overweight, and 7 children with obesity. Poor nutritional status was dominated by boys, aged 24-35 months, a history of term birth and screen time of 2 hours per day. The latency period of wave V was prolonged in the right ear (7.58 ms ± 0.48 ms) and the left ear (7.43 ms ± 0.4 ms). There was a relationship between nutritional status and the latency period of wave V BERA in AD (p=0.000, r=-0.505) and AS (p=0.001, r=-0.409). Conclusion: Poor nutritional status was associated with prolonged BERA wave V latency among toddlers with speech disorders and normal hearing, suggesting delayed maturation od the auditory pathway.

Keywords: BERA, Latency Period, Nutritional Status, Speech Delay, Wave V

INTRODUCTION

Speech and language development that is in accordance with milestones (developmental stages) is closely related to normal hearing, even though most children with speech delays show normal hearing thresholds (Rupert et al., 2023). Speech and language delay is relatively common in prescholl children, with an estimated prevalence of approximately 6% (Rupert, et al., 2023). The prevalence of speech delay in children based data from United States reported that 3.6% of children received a frist-time diagnosis of speech delay during the study period (Goodwin Cartwright et al., 2024). At RSUDZA Banda Aceh, a total of 102 children with speech disorders were recorded in 2023, 56 of whom had normal hearing, and in 2024, 56 of the 98 children with speech delays had normal hearing.

Brainstem Evoked Response Audiometry/BERA is a non-invasive auditory electrophysiological examination to objectively assess the functional integrity of the auditory system (Aditomo & Ruspita, 2021). The latency period in BERA, which is the time required for each wave to occur after an auditory stimulus is given. Latency values provide information regarding conduction velocity along the auditory pathway, which may indicate abnormalities in nerve conduction in transmitting auditory information. Much of the emphasis on wave latency in the study of hearing function and speech disorders has focused largely on wave V latency (Rupert et al., 2023). Wave V is the most prominent and reliably component BERA is commonly used to estimate hearing thresholds in children, generally used as a marker of hearing response resistance of around 5.6 milliseconds (ms) (Parker et al., 2022).

Risk factors for speech and language delays in children include a family history of communication disorders, genetic disorders, premature birth, abnormal development of facial and laryngeal structures, nutritional status, and a history of low socioeconomic status (Alzahrani et al., 2023). Nutritional status affects the development of a child's brain, even affecting the hearing system, which indirectly, if a child experiences hearing loss, can result in speech disorders in the child (Jain, 2025). Macro and micronutrient deficiencies can cause delayed maturation of the auditory pathway, as indicated by increased absolute and interpeak latencies, resulting in an increased incidence of hearing loss in children with nutritional status below the standard deviation (Jain et al., 2025). Iron deficiency during critical development periods has been associated with delayed speech and reduced verbal fluency. Zinc support auditory processing and linguistic comprehension, while omega-3 fatty acids enhance neuron communication pathway involved in language, expression and articulation (Eunice, 2026). Vitamin also contributing on growth and development of auditory pathway, especially Vitamin B12 deficiency that can cause cognitive impairment, neurodegenerative diseases, and mood disorders (Surucu et al., 2025). Research from Islamabad, Pakistan showing children well-nourished has normal speech rather than children with malnutrition (Khan et al., 2021). Research from Turkiye also showing same result, children with low iron levels and vitamin B12 deficiency is effective factors in speech delay (Serucu et al., 2025)

Speech and language delays are early signs that appear in children with developmental delays (Liang et al., 2023). Speech disorders are an indirect consequence of nutritional status below the standard deviation, leading to hearing impairment. Detecting this condition can provide an opportunity for early intervention (Suryawan et al., 2022). Therefore, by examining the BERA wave V latency and evaluating the nutritional status of children, it is possible to further assess the condition of children with speech disorders and normal hearing. Nutritional

status plays a crucial role in the hearing process and speech development of children. Therefore, researchers want to further assess the relationship between nutritional status and the BERA wave V latency period in toddlers with speech disorders and normal hearing.

METHOD

This study used a cross-sectional design with retrospective data from medical records taken at the ENT-BKL polyclinic of RSUDZA Banda Aceh for the period January 2024 to October 2025. Children are classified as having a speech disorder with normal hearing when they demonstrate impairments in both expressive and receptive speech despite normal auditory function. Hearing is assessed using Brainstem Evoked Response Audiometry (BERA), with normal hearing defined by the presence of Wave V at an intensity of 20 dB. The study sample consisted of all pediatric patients aged 1-5 years with speech disorders with normal hearing, who had undergone BERA examination.

Speech The independent variable in this study was nutritional status which categorized based on Z-Scores, Z Scores < -3 are categorized as severe undernutrition, Z-scores < -2 to > -3 are categorized as undernutrition. Z-scores > -2 to > 1 are categorized as normal nutritional status, Z-scores > 1 Categorized as overweight and Z-scores > 2 categorized as obesity. The dependent variable was the BERA wave V latency period with the measurement results of millisecond (ms). Categorical data were presented in the form of frequencies and percentages, while numerical data were presented in the form of means and standard deviations. SPSS, version 24 (IBM corp,. Armonk, NY) was used to enter and analyze the data. Bivariate test were used to determine the relationship between the BERA wave V latency period and the nutritional status of children with speech disorders and normal hearing using the spearman correlation test.

RESULTS

Table 1. Characteristics of Sample (n = 60)

Characteristics	F	%
Gender		
Male	39	65.0
Female	21	35.0
Age, months		
12 – 23	12	20.0
24 – 35	17	28.3
36 – 47	15	25.0
48 – 60	16	26.7
Address (Regency)		
Banda Aceh	20	33.3
Aceh Besar	12	20.0

Characteristics	F	%
Pidie	1	1.6
Bireuen	10	16.6
Lhokseumawe	1	1.6
Lhoksukon	1	1.6
Aceh Timur	1	1.6
Langsa	1	1.6
Takengon	3	4.0
Aceh Barat	4	6.4
Aceh Jaya	1	1.6
Aceh Barat Daya	3	4.8
Simeulue	1	1.6
Aceh Selatan	1	1.6
Parent's Occupation		
Self-employed	40	66.7
Farmer	11	18.3
Civil Servant (PNS)	7	11.7
Teacher	2	3.3
Pregnancy History		
Premature	3	5.0
Aterm	55	91.7
Postterm	2	3.3
Screen Time, hours		
None	13	21.7
1	9	15.0
2	16	26.7
3	6	10.0
4	10	16.6
> 5	6	10.0

A total of 69 samples were obtained, with the exclusion of 9 samples for incomplete data. Consequently, only 60 samples were analyzed. These were divided into 33 samples from 2024 and 27 samples from 2025. Most of the samples were male (n=39, 65%), aged 24-35 months (n=17, 28.3%), full-term (n=55, 91.7%), and averaged 2 hours of screen time (n=16, 26.6%) (Table 1).

Table 2. Characteristics of Nutritional Status on Sample

Category	Severe Undernutrition		Undernutrition		Normal Nutrition Status		Overweight		Obesity	
	n	%	n	%	n	%	n	%	n	%
Gender										
Male	14	35.9	0	0.0	19	48.7	2	5.1	4	10.3
Female	3	14.3	3	14.3	8	38.1	4	19.0	3	14.3
Age (months)										
12 – 23	4	6.7	1	1.7	4	6.7	2	3.3	1	1.7
24 – 35	3	5.0	1	1.7	11	18.3	0	0.0	2	3.3
36 – 47	5	8.3	0	0.0	6	10.0	2	3.3	2	3.3
48 – 60	5	8.3	1	1.7	6	10.0	2	3.3	2	3.3

Severe undernutrition was more prevalent in males (n=14, 35.9% vs. n=3, 14.3%). Meanwhile, undernutrition was more prevalent in females (n=3, 14.3% vs. n=0, 0%). Obesity was more prevalent in males than in females (Table 2).

Table 3. The Relationship between Nutritional Status and the Latency Period of Wave V of the BERA

		p-value	*r*
Nutritional Status	Right Ear	< 0.001	-0.505
	Left Ear	0.001	-0.409

The results of the correlation test found that malnourished toddlers had the highest wave V latency period, namely the auris dextra of 7.9 ms, and the auris sinistra of 7.6 ms (Table 3). Based on the results of the Spearman correlation test, it was found in the right ear (p = 0.000, r = -0.505) and in the left ear (p = 0.001 r = -0.409) (Table 4). These results indicate a relationship between nutritional status and the latency period of wave V BERA. The correlation value has a moderate negative relationship, namely the if nutritional status decrease, the latency period of the BERA V increases.

DISCUSSION

Recent literature shows that males predominantly experience speech delays, girls are shown to be better in the linguistic domain, in the stages of language development (Kumar et al., 2022). Normal hearing speech disorders are often found at the age of 24–35 months, researchers argue that this age range is where parents generally notice speech delays in children, especially when children are not yet able to say two-word phrases, and cannot follow simple commands, where these abilities should have been mastered by the age of 24 months (Rupert et al., 2023). In this study, 78.3% of children had screen time, children who were exposed to gadgets > 2 hours per day were at risk of experiencing speech delays 6.2 times (Dewi & Wiranadha, 2021). Screen time worsens language acquisition by reducing the quantity and quality of parent-child bonding time and children's motor play activities (Karani et al., 2022).

Meta-analysis research shows that boys are at greater risk of malnutrition, wasting, and stunting than girls (Thurstans et al., 2020). This is because boys are more active, so they experience more diarrhea, fever, and disabilities than girls and is the main cause of malnutrition in children (Haq et al., 2022). Higher testosterone levels in males are thought to play a role in delaying brain maturation, including the perisylvian areas of Broca's area, Wernicke's area, and the auditory cortex. Delayed maturation in these networks can impair phonological processing and sensorimotor integration of speech, which can increase susceptibility to phonation and speech disorders (Chilosi et al., 2021).

The latency period is the time (ms) required for wave V to occur (reaching the inferior colliculus) after a stimulus is given. The average latency period for wave V in the right auricle was 7.58 ms (±0.48 ms) and for the left auricle 7.43 ms (±0.4 ms). This is in line with the research last research which found that the left auricle was 6.33 ms and the right auricle 6.08

ms (Dewi et al., 2023). Research in India also found an increase in wave V latency in all groups of children studied (aged 0-12 years) with speech delays, compared to the control group (Mondal et al., 2023). Therefore, BERA is recommend for early detection of speech delays in children.

Research has shown that malnourished children have prolonged auditory evoked potential latencies compared with normally nourished children. In particular, severe acute malnutrition has been associated with significant prolongation of absolute wave I–V latencies and interpeak latencies compared with normally nourished children. These findings suggest that malnutrition may affect the maturation and neural conduction of the auditory nervous system and should be considered when interpreting auditory brainstem response wave I, III, and V latencies (Agarwal et al., 2023).

Literature shows that adequate nutrition, particularly protein, iron, choline, and fatty acids, contributes to neuronal structure. Malnutrition can interfere with the intake of proteins, essential fatty acids, and micronutrients that are necessary for the proper development and maintenance of cochlear hair cells and auditory nerve fibers, potentially resulting in sensorineural hearing loss. Nutrient deficiencies may also impair the integrity of the cochlear blood vessels, leading to reduced inner-ear perfusion and increased susceptibility to cochlear injury. Furthermore, inadequate levels of antioxidants, including vitamin E and selenium, together with elevated production of reactive oxygen species caused by metabolic disturbances, may promote oxidative damage to cochlear hair cells and auditory neural structures (Jain et al., 2025).

Malnutrition can adversely affect neuronal arborization, myelination, and synaptic formation within the central nervous system, thereby disrupting the transmission and processing of auditory information. Decreased synaptic density and altered neurotransmitter activity may impair neural synchrony, contributing to delayed auditory processing and difficulties in speech perception. These observations highlight the extensive impact of malnutrition on both peripheral and central auditory pathways, as well as on cognitive function. In addition, chronic inflammation associated with malnutrition may exacerbate neuronal damage and hinder the repair processes required for maintaining auditory system integrity and plasticity. Hormonal factors, particularly insulin-like growth factor 1 (IGF-1), which plays an important role in neuronal growth and synaptic plasticity, may become dysregulated in malnourished individuals, further compromising auditory development and function. Metabolic abnormalities linked to malnutrition, including hypoglycemia and dyslipidemia,

may also disrupt energy metabolism in auditory neurons, negatively affecting their survival and performance (Jain et al., 2025).

Iron as an integral component of several enzymes such as DNA synthesis, mitochondrial electron transportm catecholamine methabolism, neurotrasnmitter formation and required for lipids metabolism. Oligodendrocytes is cells responsible for myeli production that sensitive to iron deficiency which slows the process of myelination, thus preventing the increase in the myelinated nerve fibres which can impaired myelination (Sarin et al., 2023). Children with malnutrition cause abnormalities in Visual Evoked Potential and Auditory Evoked potential. The defect from myelination decreased the synaptic efficiency in auditory and visual system (Agarwal et al., 2023). Myelination is composed of 70% lipids and requires an adequate supply of energy and protein. In those experiencing malnutrition, the thickness of the myelin sheath decreases, and the speed of signal transmission between the nervous system slows, resulting in disruption of the auditory pathway and prolonged latency in waves I, II, and V of the BERA, and the Long Latency Auditory Evoked Potential (LLAEP), which assesses central auditory processing, attention, and memory (Jain et al., 2025). Recent evidence indicates that protein-energy malnutrition may affect central auditory processing in children despite relatively preserved peripheral hearing sensitivity. These auditory deficits may be related to impaired maturation and myelination of the central auditory pathway, potentially affecting the efficiency of auditory information transmission (Jain et al., 2025)

Deficiency of Thiamine (vitamin B1) also linked to Central Nervous System (CNS). Thiamine, as an essential water-soluble B vitamin that cannot be stored in significant amounts within the body, making a continuous dietary supply necessary. Its active form, thiamine pyrophosphate (TPP), serves as a coenzyme for several key enzymes involved in carbohydrate metabolism, including pyruvate dehydrogenase, α-ketoglutarate dehydrogenase, and transketolase. Because the CNS relies almost entirely on carbohydrate metabolism to meet its energy demands, it is particularly susceptible to thiamine deficiency (Gür et al., 2023).

Thiamine deficiency impairs cellular energy production in neural tissues, primarily through mitochondrial dysfunction, glutamate-induced neurotoxicity, or a combination of both mechanisms.2 Excessive activation of glutamate receptors promotes the formation of reactive oxygen species (ROS), which can directly damage cellular lipids, proteins, and DNA, ultimately leading to apoptosis or necrosis. While outer hair cells (OHCs) are generally the first cochlear structures affected by ROS-mediated injury, inner hair cells (IHCs) may also sustain additional damage beyond that caused directly by thiamine deficiency. Furthermore, ROS-

induced damage is not restricted to cochlear hair cells but may also contribute to spiral ganglion cell loss and mild degeneration of central auditory neurons (Gür et al., 2023).

A study, which examined BERA in obese adolescents, showed an increase compared to the control group (normal nutrition), with an average wave V latency of 5.6 ms in the left ear and 5.74 ms in the right ear. The test results showed a positive correlation between obesity and wave V latency. This positive correlation suggests a multifactorial relationship between obesity and auditory nerve conduction delay. One factor is low-grade inflammation caused by cytokines and oxidases released by adipose tissue. This leads to the release of reactive oxygen species (ROS) by macrophages and monocytes, ROS being reported to cause nerve tissue damage due to demyelination. An additional factor contributing to conduction delay may be decreased adiponectin in obesity, which causes insulin resistance and inflammation. Adiponectin is an adipokine secreted by adipocytes, which influences energy homeostasis and regulates glucose metabolism, fatty acid oxidation, and feeding behavior (Narra et al., 2023).

In children with good nutritional status, the causes of speech delay are multifactorial. Parents with low education will have a low stimulus pattern, and this also applies to caregivers who do not provide stimulation, especially in the first two years. The findings of this study suggest that nutritional status may influence the maturation of the central auditory pathway in toddlers with speech delay despite having normal peripheral hearing. Prolonged Wave V latency on Brainstem Evoked Response Audiometry (BERA) among children with suboptimal nutritional status may reflect delayed neurophysiological development, which could contribute to impaired speech and language acquisition.

These results highlight the importance of nutritional assessment as part of the comprehensive evaluation of toddlers presenting with speech delay. Furthermore, BERA may serve as an objective tool for assessing central auditory pathway maturation and identifying children at risk of developmental language disorders. Therefore, early nutritional intervention and a multidisciplinary approach may help optimize speech and language development outcomes in this population. The limitation of this study is further research is needed on other nutritional status indicators as well as micronutrients that affect speech disorder in individuals with normal hearing.

CONCLUSION

Among the 60 children with speech disorders and normal hearing included in the study, 17 (28.3%) were classified as malnourished, 3 (5.0%) as undernutrition, 27 (45.0%) as having normal nutritional status, 6 (10.0%) as overweight, and 7 (11.7%) as obese. The assessment of

auditory brainstem function revealed prolonged BERA wave V latency, with mean values of 7.58 ms in the right ear and 7.43 ms in the left ear. The study population was predominantly composed of male toddlers aged 24–35 months, most of whom resided in Banda Aceh. Their parents were primarily self-employed, and the majority had a history of term birth and approximately two hours of daily screen time. Furthermore, a significant relationship was observed between nutritional status and BERA wave V latency among toddlers with speech and hearing impairments. Children with poorer nutritional status tended to exhibit longer wave V latencies, suggesting that nutritional deficits may be associated with delayed auditory pathway conduction and maturation.

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