European Archives of Oto-Rhino-Laryngology (2019) 276:2457–2463
https://doi.org/10.1007/s00405-019-05501-w

OTOLOGY

Developments of children with hearing loss according to the age of diagnosis, amplification, and training in the early childhood period

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Received: 28 January 2019 / Accepted: 3 June 2019 / Published online: 7 June 2019

Abstract

Purpose The aim of this study is to investigate the effect of hearing loss during early childhood on the development of children according to the age of diagnosis, amplification and training.

Methods In the study, a total of 169 children with bilateral sensorineural hearing loss, who have the chronological average age of 26.4 months, have been examined. All children are unilateral cochlear implant users and have no known additional impairments and/or diseases other than their hearing loss. The development of children with hearing loss, divided into three groups according to age of diagnosis, amplification, and training has been identified using the Denver Development Screening Test-II (DDST-II), and then, general development and sub-development results of these age characteristics have been compared accordingly.

Results As a result of the study, 105 (62.1%) out of 169 children identified with DDST-II have been found to be normal, 48 (28.4%) of them suspicious, and 16 (9.5%) children are found to be abnormal. It appears that the children who have been diagnosed before 6 months, instrumented between 3 and 6 months, and started to auditory-verbal training are revealed to have normal skills in their personal–social, language, fine, and gross motor field capabilities. As the age of diagnosis and intervention is delayed, the rate of delay in the development domains seems to be increasing, which is statistically significant ($p < 0.001$).

Conclusions Children with hearing loss develop similar outcomes in comparison with their normal auditory peers once they are diagnosed before 6 months and benefit from early intervention services.

Keywords Hearing loss · Children · Diagnosis · Amplification · Training · Development

Introduction

Although the most significant impact of early childhood hearing loss emerges with language acquisition and speech, it also has a negative effect on the development of social skills, self-esteem, and literacy [1]. In particular, when not intervened in the early period, hearing loss from birth to 3 years of age may result in sensory, cognitive, emotional, and academic deficiencies in adulthood, due to delays in communication-language skills [2, 3]. The first 3 years of early childhood are of critical importance in terms of language acquisition, since language development does not continue at the same pace in the following period. Therefore, early diagnosis of hearing loss and appropriate early intervention are very important for normal language acquisition of children with hearing loss [4–6]. The Joint Committee on Infant Hearing (JCIH) emphasizes that early intervention services should be initiated before 6 months so as to minimize the negative effects of hearing loss [7]. Nowadays, thanks to the newborn hearing screening programs, diagnosis age of hearing loss has been decreased from 2.5–3 years to 2–3 months. Thus, early intervention services can be initiated within the age period critical for language speech and communication [8]. In many of the relevant studies, early diagnosis and early intervention are stated to have positive effects on speech, language, social, and emotional development of children with hearing loss. Children diagnosed and intervened in the first 6 months of their lives appear to show similar linguistic developmental characteristics compared to their peers with normal hearing [9, 10], while late diagnosis and late intervention

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result in limited vocabulary, grammatical problems, and academic difficulties [11].

Children with hearing loss are also at high risk of encountering social–emotional problems [12–14]. In some studies, the prevalence of social–emotional problems is reported to have been between 8 [15] and 41.3% [16]. Difficulty in communication caused by language and speech delays that occur frequently in children with hearing loss seems to bring about the ground for social and emotional problems, which adversely affects the quality of social interaction [17]. In similar studies, it is emphasized that children with hearing loss have difficulty in focusing their attention on preschool period, and therefore, they cannot maintain social interaction appropriately [18].

Early childhood is one of the critical periods in development. In this period, it is very important to identify the development of the child, support all developmental areas at the highest level, reveal the potential problems in the early period, and make the necessary interventions at an early stage [19, 20]. The effects of hearing loss on child development vary depending on factors, such as age related onset of hearing loss, degree of loss, and age of diagnosis or intervention, as well as family interest and support [21]. The aim of this study is to investigate the effect of hearing loss on early childhood in terms of development, instrumentation/amplification, and the starting age of training for children.

Materials and methods

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standard. Besides, the ethics approval for the clinical trial of the study was obtained from the Education Council of Specialty in Medicine (Date and number of decision: 13/2019).

Subjects

In the study, a total of 169 children with congenital bilateral severe and profound sensorineural hearing loss were evaluated. All of the children used single-sided cochlear implants, and none of them had any known/diagnosed disabilities or disorders. The study consisted of 92 male (54.4%) and 77 female (45.6%) children, with a chronological age average of 26.4 months (Range 18–36 months, SD: 9.6).

Table 1 illustrates data on the age when children with hearing loss were diagnosed, type of amplification they use, duration of amplification, and the starting age of auditory-verbal therapy.

In the study, the children with hearing loss were divided into three groups according to the age of diagnosis, age of amplification, and starting age of training. Of all the children with hearing loss, 54 of them were diagnosed when they were between 0 and 6 months; 67 of them between 6 and 12 months; and 48 of them between 12 and 18 months. The age that amplification was commenced was 3–6 months in 32 children, 6–12 months in 98, and 12–18 months in 39 children. Analysis of the children revealed that 21 of them started auditory-verbal therapy before 6 months; 84 of them between 6–12 months; and 64 children when they were between 12 and 18 months. Written consents were obtained from parents/mothers or fathers of the children prior to the study. The data regarding diagnosis, amplification/cochlear implantation age and the age of starting auditory-verbal therapy were obtained from patient files and family interviews.

Data tools

In the study, the 'Child Data Questionnaire' was used during family interviews, while 'Denver Developmental Screening Test-II (DDST-II)' was utilized in the evaluation of children's general developments and sub-developmental domains. DDST-II is a developmental screening test applied on children who have hearing loss and are followed in our clinic, on a regular basis. The test is conducted initially on the date when the child is first referred to our clinic, and then

Table 1 Information related to age, gender and audiological features of children with hearing loss

Features	Children with hearing loss
Number	$N = 169$
Gender	99 males (54.4%), 77 are females (45.6%)
Choronologic age (month)	26.4 months (range 18–36 months, SD: 9.6)
Diagnosis age of hearing loss (month)	11.2 months (range 0– 18 months) SD: 8.9)
Type of amplification	100% unilateral cochlear implant
Hearing age (month)	14.1 months (range 3–18 months, SD: 7.3)
Age of cochlear implant (month)	19.5 months (range 12–36, SD: 10.4)
Age of auditory-verbal therapy	15.3 months (range 6–18, SD: 5.8)

regularly applied on the 1st, 3rd, 6th, 9th, 12th, 18th, 24th, and 36th months of the follow-up. Test intervals may vary depending on the necessity. The previous DDST-II results of the children included in the study were obtained from the patient files retrospectively.

Child data questionnaire

This questionnaire was filled through face-to-face interviews held with the parents of children who participated in the study. The questionnaire consisted of 20 questions based on demographic, general health status, and hearing loss of the children. Data on the chronological age of the child, additional impairment or illness status, diagnosis age of hearing loss, type of amplification used (hearing aid and/or cochlear implant), age of hearing aid and/or cochlear implant, duration of use, and age when auditory-verbal therapy was started were collected through the questionnaire.

Denver development screening test-II (DDST-II)

Turkish validity and reliability studies of the test, which was first designed by Frankenburg and Dodds in 1967 [22], were done by Anlar and Yalaz in 1996 [23], and then revised in 2009 [24]. DDST-II is a test that can be easily applied on children aged 0–6 and plays a vital role in the early recognition of developmental deviations and the development of a child during this period. It is used to screen developmental problems in children, to validate suspicious cases with objective criteria, and to monitor children at risk from the developmental point of view.

The test consists of a total of 134 items identifying the four domains mentioned below:

1. *Personal–social development* Interactions with people, ability to meet individual needs (21 items).
2. *Fine motor development* Eye–hand coordination, ability to use small objects, problem-solving capabilities (33 items).
3. *Language development* Hearing, comprehension and use of language, receptive, and expressive language capabilities (42 items).
4. *Gross motor development* Large muscle movements (38 items) such as sitting, walking, and jumping are identified [24].

Statistical analysis

SPSS 22.0 (Statistical Package for the Social Sciences) program was used for the statistical analysis of the data obtained from the study. In the evaluation of the data, Mann–Whitney test was used to compare quantitative data, while Kruskal–Wallis test, Spearman correlation, analysis and Chi-square test were used to compare qualitative data, as well as the descriptive statistical analysis. The score $p < 0.05$ was considered as statistically significant.

Results

The average chronological age of 169 children who participated in the study was found to be 26.4 months, while the average age of diagnosis of hearing loss was 11.2 months; the average duration of amplification was 14.1 months; the average age of cochlear implantation was 19.5 months; and the average age of starting auditory-verbal training was 15.3 months (Table 1).

Results of DDST-II

Of all the children with hearing loss, whose data were analyzed with DDST-II, 105 of them (62.1%) were found to be 'normal', 48 of them (28.4%) were 'suspicious', and 16 children (9.5%) were 'abnormal'. Table 2 reveals that there is a statistically significant difference among the children's DDST-II results ($p < 0.001$). In addition to the general development of children with hearing loss, personal–social, language, fine motor, and gross motor capabilities, which are the sub-domains of DDST-II test, were also evaluated in details. According to the findings of DDST-II test, the results regarded as normal were the highest in gross motor (91.1%) and fine motor (88.2%) development domains, whereas the

Table 2 Ranges of children with hearing loss according to DDST-II results

	N	(%)	*p*
Denver Development Screening Test-II (DDST-II)			
Normal	105	62.1	< 0.001
Suspicious	48	28.4	
Abnormal	16	9.5	
Personal-social development			
Normal	112	66.3	< 0.001
Delay	57	33.7	
Language development			
Normal	110	65.1	< 0.001
Delay	59	34.9	
Fine motor development			
Normal	149	88.2	> 0.001
Delay	20	11.8	
Gross motor development			
Normal	154	91.1	> 0.001
Delay	15	8.9	
Total			
–	169	100.0	–

delay in the results of DDST-II appeared to be the highest in the domains of personal–social (66.3%) and language developments (65.1%) (Table 2). When the personal–social development domains of the children were analyzed, it was observed that 66.3% (*N*:112) of them had normal developments and 33.7% of them (*N*:57) showed a delay, which appeared to be statistically significant ($p < 0.001$). Similarly, while 110 children (65.1%) had normal language development, 59 of them (34.9%) had delayed development ($p < 0.001$). 88.2% (*N*:49) of the children were found to be with normal fine motor capabilities and 91.1% (*N*:154) of them had normal gross motor capabilities ($p > 0.001$) (Table 2).

Table 3 illustrates the distribution of DDST-II subdomain results of the children with hearing loss according to diagnosis, amplification and the age when training was commenced. When the development of children according to the age of diagnosis is analyzed, one can observe that children diagnosed between 0 and 6 months have higher outcomes with normal personal–social, language, fine and gross motor domain capabilities compared to those diagnosed over 6 months. The delay in diagnostic age goes in parallel with the rate of delay in development domains, which is statistically significant ($p < 0.001$).

93.8% of 32 children with hearing loss, who had been instrumented between 3 and 6 months, showed normal development in personal-social and language domains, while 96.9% them showed the same development in fine and gross motor domains ($p < 0.001$). Similarly, all children with hearing loss who started auditory-verbal therapy before 6 months (100%) had 'normal' fine and gross motor capabilities, 95.2% had 'normal' personal-social outcomes, and 90.5% of them had 'normal' language developments. Moreover, the rate of 'delay' in developmental domains is found to be increasing as the starting age of training is delayed ($p < 0.001$) (Table 3).

Discussion

Evaluation of development in early childhood aims to identify the cases deviating from what is normal in terms of the child's development in language and speech; as well as emotional, cognitive, and physical matters. Approximately 25–40% of children with hearing loss appear to have additional needs due to an additional impairment; and these requirements are rather predominant for speech and language, cognitive, physical, behavioral and/or emotional problems [25]. Early diagnosis and early intervention programs are very useful for identifying and monitoring the progression of the children with hearing loss in all domains of development [26].

Normal hearing is vital for optimal auditory development and verbal communication. Infants and children with hearing loss are at risk for developmental aspects, especially in speech and language acquisition [27]. Children with hearing loss who do not have the same opportunity to learn the language in due course and appropriately, fall behind their

Table 3 Ranges of the children's DDST-II sub-domain results according to diagnosis, amplification and the starting age of training

	Age range	DDST-II	PSD	LD	FMD	GMD	*p*
Age of diagnosis	0–6 months (*N*:54)	Normal	45 (83.3%)	47 (87.0%)	50 (92.6%)	52 (96.3%)	< 0.001
		Delay	9 (16.7%)	7 (13.0%)	4 (7.4%)	2 (3.7%)	
	6–12 months (*N*:67)	Normal	49 (73.1%)	43 (64.2%	58 (86.6%)	60 (89.5%)	
		Delay	18 (26.9%)	24 (35.8%)	9 (13.4%)	7 (10.5%)	
	12–18 months (*N*:48)	Normal	18 (37.5%)	20 (41.7%)	41 (85.4%	42 (87.5%)	
		Delay	30 (62.5%)	28 (58.3%)	7 (14.6%)	6 (12.5%)	
Age of amplification	3–6 months (*N*:32)	Normal	30 (93.8%)	30 (93.8%)	31 (96.9%)	31 (96.9%)	< 000.1
		Delay	2 (6.2%)	2 (6.2%)	1 (3.1%)	1 (3.1%)	
	6–12 months (*N*:98)	Normal	87 (88.8%)	85 (86.7%)	92 (93.8%)	93 (94.9%)	
		Delay	11 (11.2%)	13 (13.3%)	6 (6.2%)	5 (5.1%)	
	12–18 months (*N*:39)	Normal	24 (61.5%)	21 (53.8%)	28 (71.8%)	30 (% 76.9)	
		Delay	15 (38.5%)	18 (46.2%)	11 (28.2%)	9 (23.1%)	
Age of auditory-verbal training	3–6 months (*N*:21)	Normal	20 (95.2%)	19 (90.5%)	21 (100%)	21 (100%)	< 0.001
		Delay	1 (4.8%)	2 (9.5%)	0 (0%)	0 (0%)	
	6–12 ay (*N*:84)	Normal	68 (81.0%)	65 (77.4%)	78 (92.9%)	80 (95.2%)	
		Delay	16 (19.0%)	19 (22.6%)	6 (7.1%)	4 (4.8%)	
	12–18 ay (*N*:64)	Normal	49 (76.6%)	48 (%75.0)	57 (89.1%)	60 (93.8%)	
		Delay	15 (23.4%)	16 (25.0%)	7 (10.9%)	4 (6.2%)	

PSD personal-social development, *LD* language development, *FMD* fine motor development, *GMD* gross motor development

peers with normal hearing in terms of language, speech, cognitive, and socio-emotional developments. Early diagnosis and early intervention in children with hearing loss prevent severe language and communication delays and reduce the need for habilitation [28].

Early Diagnosis and Early Intervention Programs stress on the fact that hearing screening should be performed before 3 months of age; and that advanced audiological identification and early intervention are supposed to be performed until 6 months of age. This rule of necessity, known as 1–3–6, is of great importance for children with hearing loss in terms of benefiting from the positive effects of early diagnosis and early intervention [7, 29].The main objective of the 1–3–6 rule is to provide speech-language development appropriate for the ages of children with hearing loss, in comparison with their peers who are diagnosed later in their lives [30].

Negative effects of sensorineural hearing loss in early childhood can be minimized by neonatal hearing screening. On the other hand, late diagnosis leads to delay in speech, language, and reading skills; in addition, many children with hearing loss face with educational, occupational, and socio-economic constraints [31]. In relevant studies, it is emphasized that diagnosis of hearing loss in infants after 6 months of age leads to a delay in language-speech development, as it is a rather critical period for neural plasticity and audiological development [28]. In another study, it is reported that 95% of the 49 children with hearing loss diagnosed before 12 months of age acquired receptive and expressive language skills appropriate for their ages and that all of the children gained the typical vocabulary and language development by the age of five [32]. Similarly, it is also observed in our study that the rate of 'delay' in developmental domains increased in line with the delay of diagnosis, and that children with hearing loss diagnosed before 6 months are found to have a higher rate of "normal" social-personal, language, fine and gross motor field skills than those diagnosed between 6 and 12 months and 12 and 18 months.

Most infants who hear normally create babbling sounds whey they are around seven months, while infants with congenital hearing loss show significant delay in their early vocalization. Relevant studies emphasize that loss may encounter with delays in their developments [33]. However, in some studies comparing children who benefit from early amplification and early intervention programs before and after 6 months, it is emphasized that children who have been treated before 6 months are 1–2 years ahead in the first grade, in terms of language, cognitive and social skills when compared to others [34]. It is a fact that the sooner the hearing loss is intervened, the less its negative effects emerge. Fulcher et al. underline the fact that when children with severe and extreme hearing loss are diagnosed at an early stage, use amplification for up to three months, receive auditory-verbal training up to 6 months and a cochlear implant is inserted for up to 18 months, in the end, they can catch up with their normally hearing peers until the age of three [35].

In our study, a large proportion of children with hearing loss who were instrumented between 3 and 6 months and started auditory-verbal training before 6 months showed normal development in personal-social, language, fine and gross motor domains, whereas the delay in developmental domains increased in line with the delay in amplification and auditory-verbal training ($p < 0.001$). Similarly, Philips et al. have reported that among the children who are verbally trained and use cochlear implants, those who have started to benefit from early diagnosis and intervention programs before 6 months of age are found to have significantly better speech production than the ones starting such programs after 14 months of age [36]. Furthermore, Cupples et al. have found that the prognosis of listening and speech-language development in children with hearing loss are better with early-onset auditory-verbal trainings [37]. In other similar studies, early diagnosis of hearing loss, early amplification and auditory-verbal therapy initiated before 6 months have been revealed to be effective in the speech and language outcomes of children with hearing loss [31].

Conclusions

Hearing loss in early childhood carries a higher risk of cognitive, social and emotional problems, especially with language and speech delays, unless they are diagnosed and intervened at an early stage. Children with hearing loss develop similar outcomes in comparison with their normal auditory peers when they are diagnosed before 6 months of age and benefit from early intervention services (amplification and auditory-verbal therapy). Besides, the early cochlear implantation applied on children with hearing loss has a vital impact on the child's development in all domains. These children achieve good outcomes because of the early hearing rehabilitation and subsequent cochlear implantation (or while being assessed/ prepared for cochlear implantation). While delayed age of diagnosis and intervention adversely affect all developmental domains of a child (language, speech, social, emotional, cognitive, etc.), early diagnosis, early instrumentation and early auditory-verbal therapy seem to have a positive effect on the development of the child.

Funding None.

Compliance with ethical standards

Conflict of interest The author declares no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standard. Besides, the ethics approval for the clinical trial of the study was obtained from the Education Council of Specialty in Medicine (Date and number of decision: 13/2019).

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