Original Article

Home-based Early Intervention on Auditory and Speech Development in Mandarin-speaking Deaf Infants and Toddlers with Chronological Aged 7–24 Months

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Abstract

Background: Early auditory and speech development in home-based early intervention of infants and toddlers with hearing loss younger than 2 years are still spare in China. This study aimed to observe the development of auditory and speech in deaf infants and toddlers who were fitted with hearing aids and/or received cochlear implantation between the chronological ages of 7–24 months, and analyze the effect of chronological age and recovery time on auditory and speech development in the course of home-based early intervention.

Methods: This longitudinal study included 55 hearing impaired children with severe and profound binaural deafness, who were divided into Group A (7–12 months), Group B (13–18 months) and Group C (19–24 months) based on the chronological age. Categories auditory performance (CAP) and speech intelligibility rating scale (SIR) were used to evaluate auditory and speech development at baseline and 3, 6, 9, 12, 18, and 24 months of habilitation. Descriptive statistics were used to describe demographic features and were analyzed by repeated measures analysis of variance.

Results: With 24 months of hearing intervention, 78% of the patients were able to understand common phrases and conversation without lip-reading, 96% of the patients were intelligible to a listener. In three groups, children showed the rapid growth of trend features in each period of habilitation. CAP and SIR scores have developed rapidly within 24 months after fitted auxiliary device in Group A, which performed much better auditory and speech abilities than Group B ($P < 0.05$) and Group C ($P < 0.05$). Group B achieved better results than Group C, whereas no significant differences were observed between Group B and Group C ($P > 0.05$).

Conclusions: The data suggested the early hearing intervention and home-based habilitation benefit auditory and speech development. Chronological age and recovery time may be major factors for aural verbal outcomes in hearing impaired children. The development of auditory and speech in hearing impaired children may be relatively crucial in the first year's habilitation after fitted with the auxiliary device.

Key words: Auditory Performance; Hearing Impaired; Home-based Early Intervention; Speech Intelligible

Introduction

The benefit of early intervention for infants and toddlers with hearing loss has been a hot area of research. Before the universal newborn hearing screening (UNHS) program and genetic screening for deafness-susceptibility in newborns (GSDSN) program, children with severe and profound hearing loss could not receive proper diagnosis and management until age 3, while children with mild and moderate hearing loss would be diagnosed even later, which severely impacted the auditory and speech development of these children.[1-3] The development of UNHS program and GSDSN program allows infants and toddlers with hearing loss to enter the process of auditory and speech habilitation by receiving hearing aids (HA) and/or cochlear implantation (CI).[4]

Recent studies have paid much attention to the development of speech and language skills in children with hearing loss. It has been indicated that the amount of benefit from HA and CI in children's speech-language development is closely related to how early the child starts to use these

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devices.[5,6] In China, children with hearing loss typically enter rehabilitative training at around age of 2, and these groups of children have been widely studied in their speech and language development. For children under 2 years old, while they are not yet eligible for institution-based training, home-based intervention becomes a crucial component in early intervention,[7,8] data on early auditory and speech development in home-based intervention of infants and toddlers with hearing loss younger than 2 years are still spare.

A few years ago, we started a home-based intervention program for children who use HA or CI. This home-based intervention program provided parents of these children with hierarchical intervention plans (including instructions and materials) in auditory, speech, and language skills and with monitoring and assessment. The current study was a 24-month follow-up study on this home-based intervention program. Children with hearing loss who use HA or CI were separated into three groups based on their age starting to use the hearing devices. The study aimed to find out: (1) if there is a rapid growth in auditory and speech development in those groups; (2) if auditory and speech development in three groups is equivalent; and (3) assess the impact of chronological age and recovery time on auditory and speech development in children with hearing loss.

Methods

Participants

Ethics approval for this study was obtained from China Rehabilitation Research Center for Deaf Children. Written informed consents were obtained from all patients' parents or legal guardians.

This was a prospective study to analyze data from hearing impaired children with binaural severe and profound hearing loss who participated in the home-based early intervention in China Rehabilitation Research Center for Deaf Children. Parents participating in this parent-training program would be taught to train their children's auditory, speech, and language skills hierarchically, asked to administrate training for their children at home. The habilitation training for children was about 2 h per day and lasted 24 months in home; children, parents, and therapists would communicate face to face 1 or 1.5 h per week in rehabilitation institution, including progress and accomplishment of the last week plan, lay down, and adjust the next plan. Fifty-five children younger than 24 months enrolled at first, 6 children exited the test in half way, and 4 children went other cities or provinces for habilitation, the rest of children include 17 with severe sensorineural hearing loss and 28 with profound sensorineural hearing loss. Among them, 16 entered the home-based early intervention program between 7 and 12 months of age, 16 between 13 and 18 months of age, 13 between 19 and 24 months of age. Owing to the influential consequences of politics, economic, education, and marriage, 26 children had received bilateral HA, 19 children fitted unilateral HA and cochlear implanted on the contralateral.

The children were divided into three groups, including Group A (7–12 months), Group B (13–18 months), and Group C (19–24 months), depending on the chronological age when they first started to use HA or CI. Demographic information is shown in Table 1. Parents or caregivers were given questionnaires on the hearing and speech development of children with hearing loss at time of habilitation (baseline, 3, 6, 9, 12, 18, and 24 months) for three groups.

Material

Below were the assessment instruments to evaluate the auditory and speech development and the questionnaires.

Auditory development

The categories auditory performance (CAP) was designed by Archbold *et al*.[9] in 1995 and used in cochlear implanted children. The reliability and validity of the scale have been confirmed.[10] CAP consists of eight performance categories (from 0 to 7): The category 0–2 evaluated the detection of natural sound and verbal sound in everyday living environment; category 3 and 4 are used to assess the ability of discrimination; and category 5–7 is mainly used for evaluation of deaf children's ability to understand the meaning of the language in our daily life.

Speech development

The speech intelligibility rating (SIR) was used to assess the speech production capabilities of language, and the reliability and validity of the scale have been confirmed by other studies.[11,12] SIR consists of five categories (from 1 to 5) that based on spontaneous speech intelligibility: The category 1 and 2 indicate that connected speech is unintelligible to listeners; the category 3 and 4 manifest that speech can be intelligible to a listener who concentrates and lip-reads or has experience of a deaf person's speech; and the category 5 manifest that connected speech is intelligible to all listeners.

Test procedure

All assessments were conducted in China Rehabilitation Research Center for Deaf Children. Parents or caregivers were asked a series of questions regarding their child's

Table 1: Demographic information of 45 participants (mean ± SD)

Groups	Age 1st fitting CI or HA (months)	Left ear (dB HL)		Right ear (dB HL)	
		Unaided PTA	Aided PTA	Unaided PTA	Aided PTA
Group A (*n* = 16)	9.38 ± 1.59	88.75 ± 12.17	42.81 ± 6.58	86.25 ± 8.06	48.44 ± 5.98
Group B (*n* = 16)	16.00 ± 1.79	89.38 ± 8.92	50.31 ± 9.61	92.19 ± 8.94	49.13 ± 9.81
Group C (*n* = 13)	21.00 ± 1.87	95.00 ± 11.18	43.08 ± 7.55	90.77 ± 8.86	49.02 ± 7.99

CI: Cochlear implantation; HA: Hearing aids; PTA: Pure tone average (0.5 kHz, 1 kHz, 2 kHz, 4 kHz); SD: Standard deviation; HL: Hearing level.

spontaneous auditory responses to sounds in the natural situation and meaningful using speech in the process of evaluation. These performed by audiologists with parents or caregivers at regular intervals, such as baseline, 3, 6, 9, 12, 18, and 24 months after hearing intervention and habilitation.

Statistical analysis

SPSS version 17.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Data were analyzed by repeated measures analysis of variance (ANOVA). Data were shown as mean ± standard deviation (SD). This research used a 3 × 7 mixed model ANOVA. Between-subjects factor is a chronological age for children with hearing loss, including 7–12 months (Group A), 13–18 months (Group B), and 19–24 months (Group C). Within-subjects factor is recovery time (baseline, 3, 6, 9, 12, 18, and 24 months) with repeated measure. A $P < 0.05$ was regarded as statistically significant.

Results

Auditory development

The auditory development of children relative to recovery time is shown in Figure 1. Three groups all showed continuous auditory development in the course of 24 months hearing intervention and habilitation. Table 2 shows CAP scores of 45 hearing impaired children between 0 and 24 months. Three groups (A–C) achieved the mean score of 4.0, 3.3, and 3.0 points after 12 months of habilitation. Furthermore, three groups (A–C) children reached the mean score of 5.6, 5.1, and 4.8 points at 24 months after first fitted at their mean chronological age of 9, 16, and 21 months, respectively.

The analyses did not show any significant interaction between chronological age and recovery time ($F = 1.772$, $P = 0.094$). However, the main effect showed a significantly difference in chronological age ($F = 3.407$, $P = 0.043$) and recovery time ($F = 603.443$, $P = 0.000$) for CAP. After multiple comparison, there were significant differences between Groups A and B ($P = 0.028$) and Groups A and C ($P = 0.012$), but there was no significant difference between Groups B and C ($P = 0.769$); there were extremely significant differences between 0, 3, 6, 9, 12, 18, and 24 months in Group A, Group B, and Group C, respectively (all $P < 0.01$).

The number of participants that achieved in each CAP category at each interval recorded in Table 3. At before fitted, 38 patients reached at category 0, indicating that 84% of the patients were not aware of the environmental sound. Sixteen patients reached category 3 and 15 patients reached category 4 at 12 months, indicating that 36% of the patients were able to response to speech sounds and 33% of patients could discriminate of some speech sound. Twenty-one patients reached category 5 and 14 patients reached category 6 at 24 months, indicating that 47% and 31% of the patients were able to understand common phrases and conversation without lip-reading, respectively; only 4% of the patients could use of telephone with known listener.

Speech development

The speech development of children relative to the recovery time is shown in Figure 2. There were no obvious changes in 0–6 months, three groups all showed continuous speech development in the course of 6–24 months habilitation. Table 4 shows SIR scores of 45 hearing impaired children between 0 and 24 months of habilitation. Figure 2 shows that three groups (A–C) achieved the mean score of 2.7, 2.3, and 2.1 points in the recovery time of 12 months. Furthermore, three groups (A–C) children reached the mean score of 3.8, 3.4, and 3.1 points after 24 months habilitation.

The main effect showed a significant difference in group ($F = 7.373$, $P = 0.002$) and recovery time ($F = 288.835$, $P = 0.00$) for SIR. After multiple comparison, there were significant differences between Group A and Group B ($P = 0.042$), and Group A and Group C ($P = 0.002$), but there was no significant difference between Group B and Group C ($P = 0217$), and there are no significant differences between 0, 3, and 6 months in Group A, Group B, and Group C, respectively ($P > 0.05$), and there were extremely significant differences between 9, 12, 18, and 24 months in Group A, Group B, and Group C, respectively (all $P < 0.05$). The analysis showed a significant interaction between chronological age and recovery time ($F = 2.868$, $P = 0.04$), the simple effect analysis suggested that there were

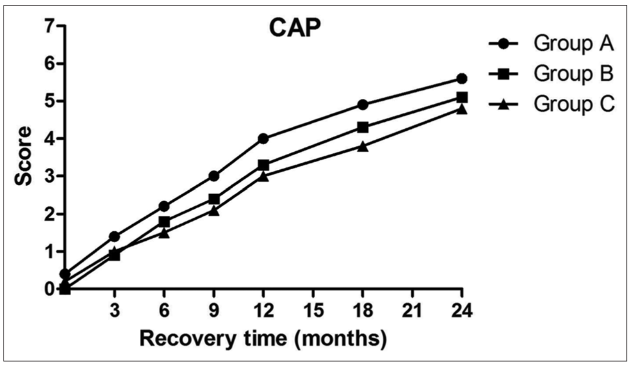

Figure 1: Results of categories auditory performance (CAP) in Group A (7–12 months), Group B (13–18 months), and Group C (19–24 months) dependent on recovery time (0, 3, 6, 9, 12, 18, and 24 months).

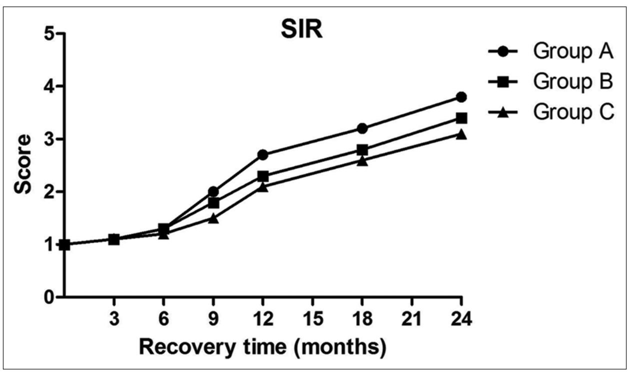

Figure 2: Results of speech intelligibility rating (SIR) in Group A (7–12 months), Group B (13–18 months), and Group C (19–24 months) recovery time (0, 3, 6, 9, 12, 18, and 24 months).

significant differences between Group A and Group C in 9, 12, 18, and 24 months, respectively (all $P < 0.05$).

The number of patients that achieved in each SIR category at each interval recorded in Table 5. All patients were not higher than category 2 at before fitted, 3 months and 6 months, indicating that connected speech was unintelligible to listeners. Twenty (44%) patients reached category 3 that connected speech was intelligible to a listener at 12 months. Nineteen (42%) patients reached category 4, and only 2% of the patients could be intelligible to all listeners at 24 months.

Discussion

This follow-up study of home-based early intervention in hearing impaired children suggested that the age of starting to use HA or CI may be related to the performance of auditory skills, use of meaningful speech, oral speech, and expressive language. Whenever they have fitted with aural device, most of children with hearing loss younger than 24 months will stay at home due to their weak self-care ability, home-based early intervention will be implemented during this critical period, not only accept the auditory stimuli, but also enter auditory

Table 2: CAP of 45 participants before the recovery time of 24 months (mean ± SD)

Groups	Before fitted	After fitted					
		3 months	6 months	9 months	12 months	18 months	24 months
Group A	0.4 ± 0.5	1.4 ± 0.6	2.2 ± 0.7	3.0 ± 0.6	4.0 ± 0.9	4.9 ± 0.9	5.6 ± 0.8
Group B	0.0 ± 0.0	0.9 ± 0.7	1.8 ± 0.9	2.4 ± 0.6	3.3 ± 0.8	4.3 ± 0.7	5.1 ± 0.7
Group C	0.2 ± 0.6	1.0 ± 0.7	1.5 ± 0.9	2.1 ± 0.9	3.0 ± 0.9	3.8 ± 0.9	4.8 ± 0.7
Total	0.2 ± 0.4	1.1 ± 0.7	1.8 ± 0.9	2.5 ± 0.8	3.4 ± 0.9	4.3 ± 0.9	5.2 ± 0.8

SD: Standard deviation; CAP: Categories auditory performance.

Table 3: The patients in each CAP category before fitted, 3, 6, 9, 12, 18, and 24 months after fitted HA or CI (*N*=45, *n* (%))

CAP	Before fitted	After fitted					
		3 months	6 months	9 months	12 months	18 months	24 months
0	38 (85)	9 (20)	3 (7)	0	0	0	0
1	6 (13)	23 (51)	12 (27)	5 (11)	0	0	0
2	1 (2)	13 (29)	20 (44)	15 (33)	8 (18)	0	0
3	0	0	10 (22)	22 (49)	16 (36)	8 (18)	0
4	0	0	0	3 (7)	15 (33)	17 (38)	8 (18)
5	0	0	0	0	6 (13)	15 (33)	21 (47)
6	0	0	0	0	0	5 (11)	14 (31)
7	0	0	0	0	0	0	2 (4)

CAP: Categories auditory performance; CI: Cochlear implantation; HA: Hearing aids.

Table 4: SIR scale of 45 participants before the recovery time of 24 months (mean ± SD)

Groups	Before fitted	After fitted					
		3 months	6 months	9 months	12 months	18 months	24 months
Group A	1.0 ± 0.0	1.1 ± 0.3	1.3 ± 0.5	2.0 ± 0.4	2.7 ± 0.5	3.2 ± 0.4	3.8 ± 0.5
Group B	1.0 ± 0.0	1.1 ± 0.3	1.3 ± 0.4	1.8 ± 0.4	2.3 ± 0.7	2.8 ± 0.5	3.4 ± 0.5
Group C	1.0 ± 0.0	1.1 ± 0.3	1.2 ± 0.4	1.5 ± 0.5	2.1 ± 0.6	2.6 ± 0.7	3.1 ± 0.5
Total	1.0 ± 0.0	1.1 ± 0.3	1.3 ± 0.4	1.7 ± 0.5	2.4 ± 0.6	2.9 ± 0.6	3.4 ± 0.6

SD: Standard deviation; SIR: Speech intelligibility rating.

Table 5: The patients in each SIR category before fitting, 3, 6, 9, 12, 18, and 24 months after fitted HA or CI (*N*=45, *n* (%))

SIR	Before fitted	After fitted					
		3 months	6 months	9 months	12 months	18 months	24 months
1	45 (100)	41 (91)	33 (73)	11 (24)	4 (9)	0	0
2	0	4 (9)	12 (27)	33 (73)	21 (47)	10 (22)	1 (2)
3	0	0	0	1 (3)	20 (44)	30 (60)	24 (54)
4	0	0	0	0	0	5 (18)	19 (42)
5	0	0	0	0	0	0	1 (2)

SIR: Speech intelligibility rating; CI: Cochlear implantation; HA: Hearing aids.

and speech habilitation training, the parent-infant and -toddler program offers intervention services provided at home for families with hearing impaired children. The program information (e.g., resources, strategies, objectives, methods of communication) was provided to the parents or caregivers through 1- or 1.5-h sessions (e.g., questions, performance, progress, methods, plans) each week and developmental progress was monitored through 3- or 6-month assessments by therapists and audiologists. In this research, home-based early intervention and developmental assessments help families make decisions about mode of communication and other intervention strategies, and also lay a good foundation for deaf children in the whole course of habilitation.

During the first 6 months, Group A behaved quietly, seemed to have grown accustomed to the settings and made a great spurt between 6 and 24 months after fitted acoustic device and outperformed Group B and Group C. The results showed that auditory performance and speech intelligible in hearing impaired children younger than 12 months of chronological age of starting to use device were significantly higher than children over 12 months of chronological age, the effects of early intervention may be better to prevent and lessen the developmental disorder caused by hearing loss. As shown in Tables 2 and 4, we can observe value-added by 2.3 points and 1.3 points in the first year rehabilitation for CAP and SIR, respectively, and value-added by 1.8 points and 1.0 point in the second year. Those results showed that the first year's performance of CAP and SIR in hearing impaired children has significantly improved, and the advancement is much better than the second years' performance. We further compared those results with the study of deaf children evaluated by the CAP and SIR tests,[13] those comparisons suggested that deaf children made better progress in the first year habilitation, this tendency was consisted with that seen for other studies,[14-16] indicating that auditory and speech development in children with hearing loss may be relatively crucial in the first year's habilitation. In the clinical work, we should pay much attention on home-based early intervention in deaf infants and toddlers and encourage parents or caregivers to participate in habilitation activities. To evaluate the auditory and speech development in infants and toddlers is a big challenge as they cannot concentrate and cooperate with the subjective method. Thus, Mandarin word list was not used in assessment but parental questionnaires were adopted in this research. A long-term follow-up of early intervention is needed to determine speech recognition in next research steps.

In this research, the development of auditory and speech was noticeable better in children fitted HA or CI younger than 12 months of chronological age, our results consisted with the results reported by Tomblin *et al*.[17] that hearing and speech growth were more rapid in children fitted and implanted as infants than those fitted and implanted as toddlers. The possibility was due to the deprivation of early auditory stimulation and speech acquisition. Auditory stimulation and habilitation aimed to improve an increase in auditory and speech development, age of starting to use device may be a major factor for the development of auditory and speech in early intervention, the earlier fitted with acoustic device, and the better adapted themselves to the change quickly in hearing impaired children. However, we found that partial children were underdeveloped even if they have taken 24 months habilitation. The degree of hearing loss, education environment, economic level, parental involvement, intelligence may also impact on the effect of habilitation, but studies on these factors have not yet been accomplished.

This study followed up 45 Mandarin-speaking children with hearing impaired children, who were not aware of environmental sound and had unintelligible connected speech before wearing the auditory device. After 24 months of habilitation, 78% of the patients were able to understand common phrases and conversation without lip-reading, 96% of the patients were intelligible to a listener. We compared CAP and SIR with Fang *et al*.'s report,[13] Fang *et al*. followed up Mandarin-speaking deaf children for 5 years in CAP and SIR (n = 85, age ranging from 0 to 5 years old), the median of CAP achieved 5 scores and SIR became 3 scores after 2-year CI, those results were slightly below the average of CAP (n = 45, age ranging from 7 to 24 months, mean = 5.2, Table 2) and SIR (mean = 5.2, Table 4), especially lower than the average of CAP (mean = 5.6, Table 2) and SIR (mean = 3.8, Table 4) in Group A, further indicated the age effect of hearing intervention and home-based habilitation. Fulcher *et al*.[18] found most children with severe and profound hearing loss who (1) were early diagnosed, (2) received amplification by 3 months or CI by 6 months, and (3) enrolled into early intervention by 6 months, were able to keep up with hearing peers by 3 years of age on speech and language skills. In our research, most of the patients have not reached optimal auditory performance and speech intelligible in 24 months habilitation, only 4% could use a telephone with known listener, 2% were fully intelligible to all listeners, we need to track and follow-up these patients in further study.

In conclusion, with 24 months of home-based early intervention, 78% of the patients were able to understand common phrases and conversation without lip-reading; 96% of the patients were intelligible to a listener. The study indicated that children fitted younger than 12 months of chronological age perform overall better than those children fitted over 12 months old. The first 12 months' habilitation was a key stage for auditory and speech development in hearing impaired children after fitted with the aural device.

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