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Original Article

Development of receptive vocabulary and verbal intelligence in Japanese children with unilateral hearing loss

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ABSTRACT

Objective: In the past, it was believed that unilateral hearing loss has a minimal impact on the speech and language development in children. However, several studies have suggested that some school-age children with unilateral hearing loss have learning impairments in language. In the present study, we first examined whether preschool-age children with unilateral severe-to-profound hearing loss (UHL) have delays in the development of receptive vocabulary and verbal intelligence. In the follow-up study, we tested the children again after school admission. The objective of the present study was to reveal the development of receptive vocabulary and verbal intelligence from preschool to school years in children with UHL.
Methods: Fifteen Japanese preschool-age children with UHL and a control group of 20 age-matched Japanese children with bilateral normal hearing (NH), who were examined because articulation disorder was suspected, were enrolled in this study. The development of receptive vocabulary and verbal intelligence was evaluated using the Picture Vocabulary Test-Revised (PVT-R) and the Wechsler Intelligence Scale, respectively. The present retrospective study was approved by the Committee for Medical Ethics of Tokushima University Hospital (#3801).
Results: The scaled score (SS) of the PVT-R and verbal intelligence quotient (VIQ)/verbal comprehension index (VCI), but not performance intelligence quotient/perceptual reasoning index in children with UHL were significantly lower than those in the control children with NH at preschool-age. The SS of the PVT-R and VIQ/VCI in children with UHL significantly improved after school admission. In the subgroup analysis, the SS of the PVT-R in the lower receptive vocabulary group of children with UHL at preschool-age was significantly increased after school admission, but the SS in the normal and higher receptive vocabulary group of children with UHL at preschool-age were still around the standardized mean of SS after school admission.
Conclusion: These findings suggest that the development of receptive vocabulary and verbal intelligence was delayed in preschool-age children with UHL and that most of them caught up to exhibit normal language ability after school admission.

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1. Introduction

Unilateral hearing loss (UHL) affects about 3–6% of school-age children [1]. In the past, it was believed that unilateral hearing loss has a minimal impact on the speech and language development of children. However, several reports have suggested that some school-age children with unilateral hearing loss have educational and/or behavior problems, and receive additional educational assistance [2,3]. Recently, Lieu, et al. reported that school-age children with UHL showed worse oral language scores than those of their brothers with normal hearing [4].

Additionally, children with UHL experience difficulties with speech perception in noisy environment [5,6]. Since language acquisition requires sufficient exposure to language during the critical period in children [7], it is possible that children with UHL may develop a speech and language development delay [8].

Currently, universal newborn hearing screening has been adopted worldwide, and it is now possible to evaluate speech and language development in preschool age children with UHL longitudinally. It was recently reported that preschool-age Swedish children with unilateral hearing loss showed a delayed language development [9].

In the present study, we first examined whether preschool-age, Japanese children with severe-to-profound UHL have delays in the development of receptive vocabulary and verbal intelligence. In the follow-up study, we tested the same children again after school admission. Therefore, the objective of this study was to determine receptive vocabulary and verbal intelligence development, from preschool to elementary school years, in children with UHL.

2. Materials and methods

In the present study, a retrospective chart review was performed, and 15 Japanese preschool-age children (mean age: 67.0 ± 8.3 months) with UHL without intellectual disability were enrolled. Their intellectual disability was evaluated using the Wechsler Intelligence Scale and all IQs except verbal one were within the normal ranges. Their mean pure-tone hearing threshold averaged across 500, 1000 and 2000 Hz was classified according to the classification of degree of hearing loss made by the American Speech-Language-Hearing Association (ASHA): slight hearing loss (HL) is defined as HL ranging from 16 to 25 dB; mild HL, from 26 to 40 dB; moderate HL, from 41 to 55 dB; moderately severe HL, from 56 to 70 dB; severe HL, from 71 to 90 dB; and profound HL, > 91 dB [10]. The children with UHL had a mean pure-tone hearing threshold if more than 80 dB in the affected ear and less than 15 dB in the opposite ear. Their types of hearing loss were all fixed sensorineural hearing loss and they did not use hearing aids or frequency modulation (FM) systems in classrooms. The control group of 20 age-matched Japanese preschool-age children (mean age: 62.6 ± 8.1 months) with bilateral normal hearing (NH) without intellectual disability was also enrolled. They were examined in outpatient care because articulation disorder was suspected. Their intellectual disability was evaluated using the Wechsler Intelligence Scale and all IQs were within the normal ranges. Their mean pure-tone hearing threshold was less than 15 dB in both ears. The present retrospective study was approved by the Committee for Medical Ethics of Tokushima University Hospital (#3801).

To evaluate the receptive ability of the Japanese vocabulary, we used the Japanese version of the Picture Vocabulary Test-Revised (PVT-R), which is a localized version of the Peabody Picture Vocabulary Test-Revised [11] for Japanese language users (https://www.nichibun.co.jp/kensa/detail/pvt_r.html, Nihon Bunka Kagakusha Co., Ltd.). The age-adjusted scaled score (SS) was used as a standardized index of integer from 1 to 19 with a mean score of 10 and a standard deviation (SD) of 3.

To evaluate verbal intelligence, we used verbal intelligence quotient (VIQ) of the Japanese version of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) [12] for 46–85-month-old children and the verbal comprehension index (VCI) of the Japanese version of the Wechsler Preschool and Primary Scale of Intelligence-The Third Edition (WPPSI-III) [13] for 30–87-month-old children (https://www.nichibun.co.jp/kensa/detail/wppsi3.html, Nihon Bunka Kagakusha Co., Ltd.) as an index. We also used the verbal comprehension index (VCI) of the Japanese version of the Wechsler Intelligence Scale for Children-The Fourth Edition (WISC-IV) [14] for 60–203-month-old children (https://www.nichibun.co.jp/kensa/detail/wisc4.html, Nihon Bunka Kagakusha Co., Ltd.) as an index. To evaluate performance intelligence at preschool-age, we used performance intelligence quotient (PIQ) of the Japanese version of the WPPSI and the perceptual reasoning index (PRI) of the Japanese version of the WPPSI-III as an index. Standardized scores with a mean score of 100 and SD of 15 were used for the VIQ/VCI and PIQ/PRI.

In the PVT-R evaluation, 15 preschool-age children with UHL (mean age: 67.0 ± 8.3 months) were first tested with the PVT-R, and in the follow-up study, the same children (mean age: 88.5 ± 9.3 months) were tested again with the PVT-R 12.9 ± 7.0 months after school admission. The mean period between the preschool PVT-R and the follow-up PVT-R after school admission was 21.3 ± 10.0 months. In the Wechsler Intelligence Scale evaluation, 8 of 15 preschool-age children with UHL (mean age: 64.8 ± 5.2 months) were tested with the WPPSI/WPPSI-III and 11 of 15 children with UHL (mean age: 95.5 ± 13.7 months) were tested with the WISC-IV 18.3 ± 12.9 months after school admission. No children with UHL suffered from otitis media with effusion between the preschool and follow-up PVT-R.

Statistical analysis was performed using Student's *t*-test, Welch's t-test and paired *t*-test (Statcel version 3, OMS Publishing Inc, Saitama, Japan). $p < 0.05$ was considered statistically significant.

3. Results

The mean SS of 6.8 ± 3.1 in the PVT-R at preschool-age of 67.0 ± 8.3 months in children with UHL was significantly

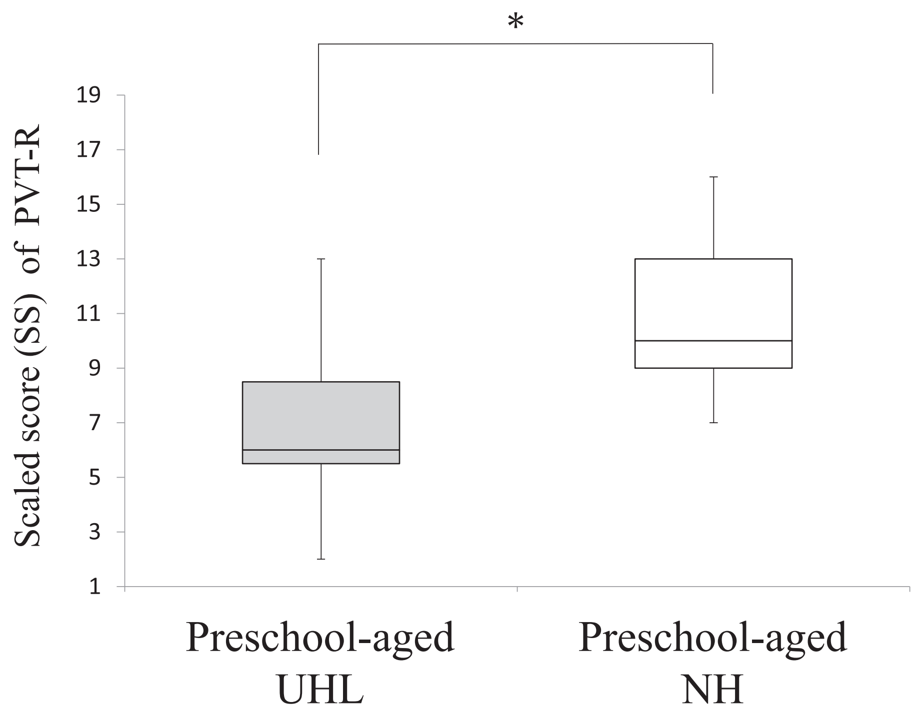

Fig. 1. Comparison of the scaled score (SS) of PVT-R in preschool-aged children with unilateral severe-to-profound hearing loss (UHL) and bilateral normal hearing (NH). UHL: n=15, NH: n=20. * p=0.0001.

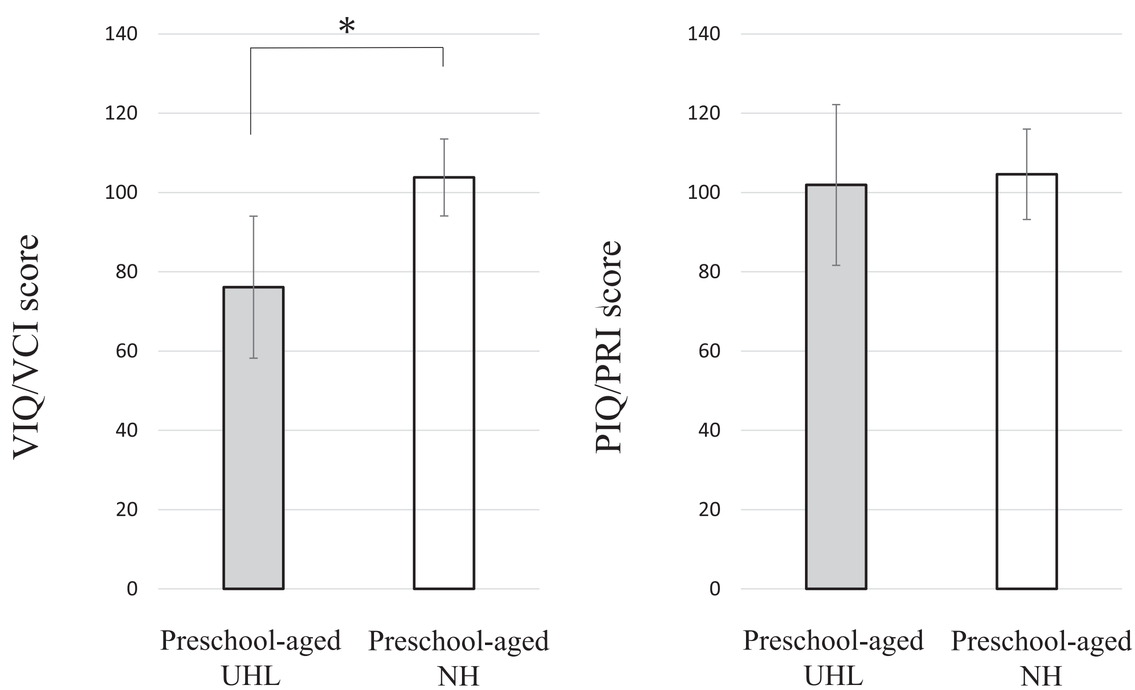

Fig. 2. Comparison of verbal intelligence quotient (VIQ)/verbal comprehension index (VCI) and performance intelligence quotient (PIQ)/perceptual reasoning index (PRI) scores in preschool-aged children with unilateral severe-to-profound hearing loss (UHL) and bilateral normal hearing (NH). UHL: n=8, NH: n=20. *p=0.005.

lower than that of 11.0 ± 2.6 at preschool-age of 62.6 ± 8.1 months in age-matched control children with NH (t(33)= -4.334, p=0.0001) (Fig. 1). The mean VIQ/VCI score of 76.1 ± 19.9 at preschool-age of 64.8 ± 5.2 months in children with UHL was significantly lower than that of 103.8 ± 8.5 at preschool-age of 63.6 ± 7.6 months in age-matched control children with NH (t(8.052)= -3.793, p=0.005) (Fig. 2). However, the mean PIQ/PRI score of 101.9 ± 20.3 at preschool-age in children with UHL was not different from that of 104.6 ± 11.4 at preschool-age in age-matched control children with NH (t(8.847)= -0.358, p=0.73) (Fig. 2).

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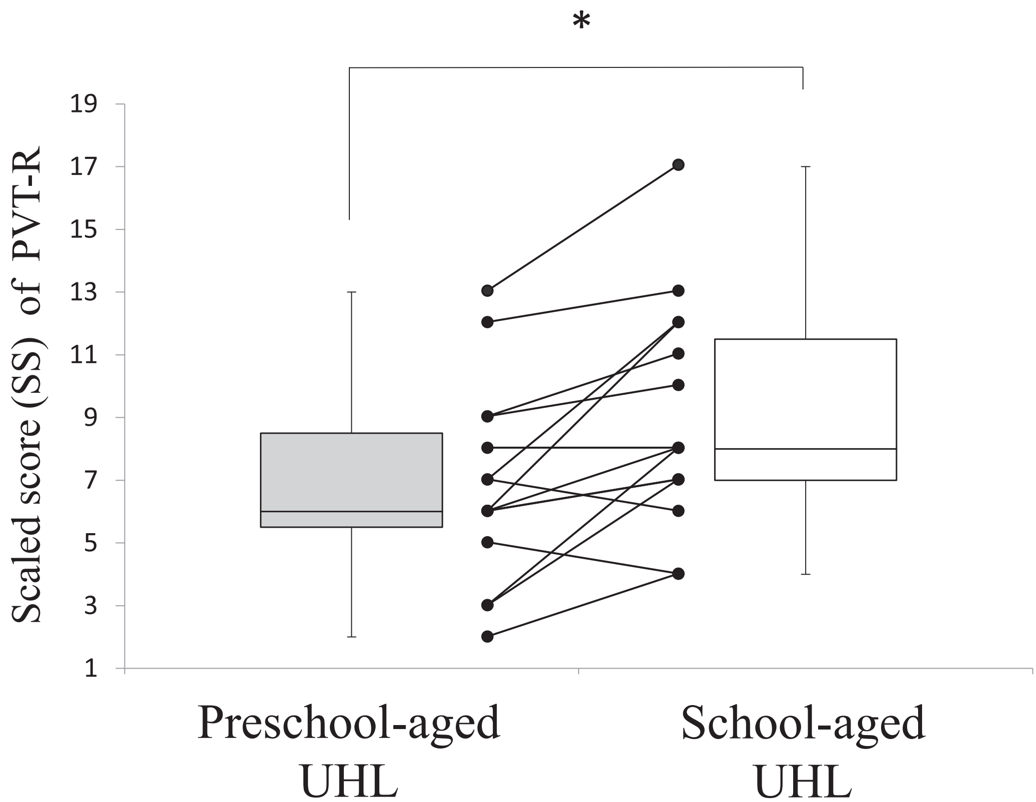

Fig. 3. Comparison of the scaled score (SS) of PVT-R in preschool-aged and school-aged children with unilateral severe-to-profound hearing loss (UHL). n=15. $^*p$=0.002.

In children with UHL, the mean SS of 6.8 ± 3.1 in the PVT-R at preschool-age of 67.0 ± 8.3 months was significantly increased to 8.9 ± 3.6 at school-age of 88.5 ± 9.3 months ($t(14)$= -3.756, p=0.002) (Fig. 3). Since the SS of 10 is a standardized mean with an SD of 3 in the PVT-R, we divided the children with UHL into two groups: the normal and higher receptive vocabulary group with the SS of ≥ 7 (mean – 1 SD) and the lower receptive vocabulary group with the SS of ≤ 6 at preschool-age. In the lower receptive vocabulary group, the mean SS of 4.6 ± 1.7 at preschool-age of 65.0 ± 7.9 months was significantly increased to 7.1 ± 2.5 at school-age of 85.1 ± 7.7 months ($t(7)$= -3.035, p=0.019) (Fig. 4a). However, in the normal and higher receptive vocabulary group, the mean SS of 9.3 ± 2.4 at preschool-age of 69.3 ± 8.8 months was not changed to 11.0 ± 3.6 at school-age of 92.3 ± 10.0 months ($t(6)$= -2.121, p=0.078) (Fig. 4b). In children with UHL, the mean of VIQ/VCI score of 76.1 ± 19.9 at preschool-age of 64.8 ± 5.2 months was significantly increased to the mean of VIQ/VCI score of 103.1 ± 16.9 at school-age of 95.5 ± 13.7 month ($t(17)$= -3.192, p=0.005) (Fig. 5).

4. Discussion

In the PVT-R at preschool-age children, the mean SS of 6.8 in children with UHL was lower than that of 11.0 in the age-matched control children with NH. Therefore, it is suggested that the development of receptive vocabulary at preschool-age was delayed in children with UHL, compared with children with NH. In the WPPSI or WPPSI-III at preschool-age, the mean VIQ/VCI score of 76.1 in children with UHL was around the lower limit of the normal VIQ/VCI score range and lower than that of 103.8 in the age-matched control children with NH, although PIQ/PRI scores were around 100 at preschool-age in children with both UHL and NH. Therefore, it is suggested that the development of spoken language capabilities at preschool-age was also delayed in children with UHL, compared with children with NH. All these findings suggest that the development of language was delayed in preschool-age children with UHL without a delay in performance development. A systematic review showed that the majority of the recent studies suggested poorer speech and language testing results in children with UHL [15]. It has also been suggested that preschool-age children with UHL showed poor outcomes in some aspects of language acquisition [16].

Unilateral hearing loss disrupts binaural processing of the auditory system, including binaural summation, head shadow effect, squelch effect, and sound localization [17–19]. Our previous study reported that speech recognition ability of school-age children with UHL was decreased, compared with that of the age-matched children with NH in a noisy environment, but not in a quiet environment [20]. This suggesting that preschool-age children with UHL encounter difficulties in understanding speech in noisy environments. Therefore, it is possible that the acquisition of language is delayed in preschool-age children with UHL, because UHL prevents

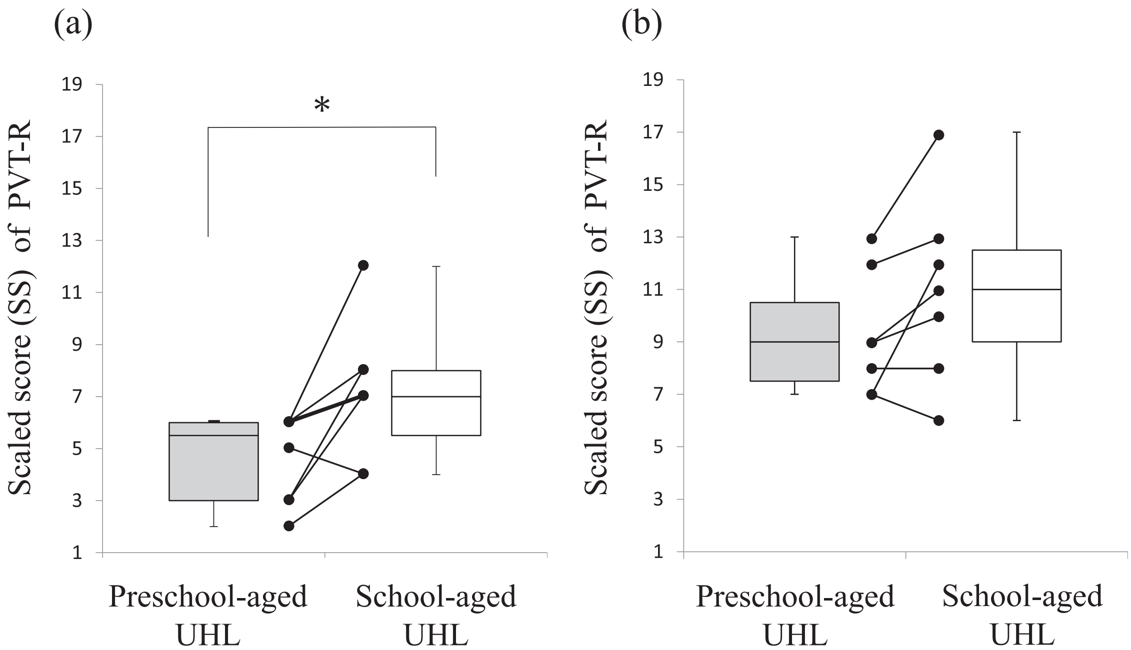

Fig. 4. Changes in the scaled score (SS) of PVT-R in children with unilateral severe-to-profound hearing loss (UHL) after school attendance. (a) Children with UHL whose preschool SS was below 6 (*n*=8). (b) Children with UHL whose preschool SS was over 7 (*n*=7). *p=0.019.

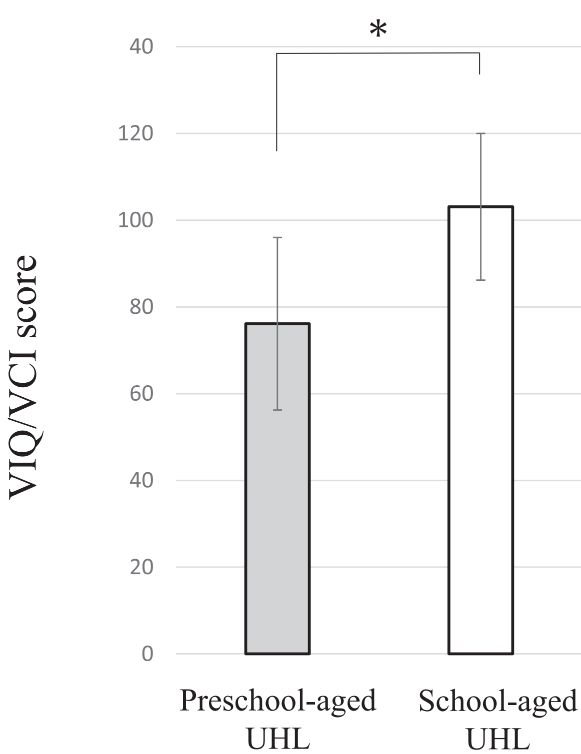

Fig. 5. Changes in the verbal intelligence quotient (VIQ)/verbal comprehension index (VCI) score in children with unilateral severe-to-profound hearing loss (UHL) after school attendance. Preschool: *n*=8, after school attendance: *n*=11. * p=0.005.

children from hearing speech sound, vocabulary, and grammatical structure of language to the degree necessary for language acquisition in noisy environments at home and at a day nursery.

In the PVT-R, the mean SS of 6.8 of children with UHL at preschool-age was increased to 8.9 after school admission. In the subgroup analysis, the mean SS of 4.6 in the lower receptive vocabulary group (SS of ≤ 6) of children with UHL (8/15, 53%) at preschool-age was increased to 7.1 after school attendance. The mean SS of 9.3 in the normal and higher receptive vocabulary group (SS of ≥ 7) of children with UHL (7/15, 47%) at preschool-age was 11.0, which is still around the standardized mean of SS (10) after school admission. These findings suggest that more than half of children with UHL had a delay in receptive vocabulary at preschool-age, which improved after school admission. VIQ/VCI score of 76.1 in children with UHL at preschool-age was increased to VCI score of 103.1 after school admission. These findings suggest that the delayed development of verbal intelligence in children with UHL at preschool-age also improved to normal development after school admission. All these findings suggest that the development of receptive vocabulary and verbal intelligence was delayed in preschool-age children with UHL and that most of them caught up exhibit normal language ability after school admission.

In the present study, no children with UHL used a hearing aid or an FM system in classrooms. Lieu, et al. reported that despite school-age children with unilateral hearing loss who did not received any form of auditory amplification, their VIQ significantly increased, and vocabulary score tended to increase over time, suggesting that school-age children with unilateral hearing loss improve their language skills at a faster rate than their age-matched peer [21]. Therefore, it is suggested that the catch-up mechanism improves the receptive ability of the vocabulary in the lower receptive vocabulary group of children with UHL in the present study. Lieu, et al. also reported that VIQ improved in school-age children with

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unilateral hearing loss who received individualized education [21]. Although children with UHL in the present study did not receive any specific education plans, in Japanese elementary school classrooms, a preferred seating was recommended for children with unilateral deafness when facing a hearing ear toward the teacher, who acknowledged that unilateral deafness as a hearing disability and sometimes provide educational assistance for them. The cares may facilitate compensation of the delay in the development of language in children with UHL in the present study. However, three children with UHL (two in the lower receptive vocabulary group and one in the normal and higher receptive vocabulary group before school admission) who showed low scores of SS (≤ 6) after school admission still had a delay in receptive vocabulary.

Speech and language delays have been suggested to occur in some children with unilateral hearing loss, but it is unclear whether the children catch up as they grow older [2,3]. Recently, universal newborn hearing screening has been implemented, and unilateral congenital deafness can be identified shortly after birth. The present longitudinal study suggested that children with UHL were at a risk of language delay at preschool-age and that most of them caught up after they entered elementary school. Appropriate early interventions are expected helpful to facilitate the catch-up. Recommended intervention for children with unilateral deafness is usually preferential classroom seating at a minimum distance from the teacher with the normal hearing ear oriented towards the teacher. However, our previous study suggested that even at a typical preferred seating, the speech recognition ability of school-age children with UHL was decreased in noisy working classrooms of elementary school [19].

Contralateral routing of signals and bone-anchored hearing aids effectively address the head shadow effect, but not restore bilateral auditory input in children with unilateral deafness [22,23]. Cochlear implantation may be an effective treatment option for children with unilateral deafness, but a high level of evidence is lacking [24]. The FM system, a personal assistive device that is used as a school-based intervention for children with hearing loss, amplifies the teacher's voice relative to the background noise [25]. In our previous study, an FM receiver fitted into the normal hearing ear improved the speech recognition ability of children with UHL in noisy environment, such as the listening condition in elementary school classrooms [20]. Therefore, the FM system may further facilitate compensation of the delay in the development of language in children with unilateral deafness after school admission, although this hypothesis needs to be proved in further studies. Moreover, the screening of children with UHL who have a delayed language development and the appropriate timing of the intervention for the catch-up also have to be clarified in further studies.

5. Conclusion

In conclusion, the development of receptive vocabulary in the PVT-R and verbal intelligence, but not performance intelligence in the Wechsler Intelligence Scale was delayed in more than half of the preschool-age children with UHL. However, children with UHL who had delays in the development of language at preschool-age caught up in term of vocabulary and verbal intelligence after school admission. Further studies are needed to determine what kinds of auditory amplification or educational assistance are effective in compensating for the delay in language development in children with unilateral deafness.

Declaration of Competing Interest

The authors declare no conflicts of interest in this study.

References

[1] Ross DS, Visser SN, Holstrum WJ, Qin T, Kenneson A. Highly variable population-based prevalence rates of unilateral hearing loss after the application of common case definitions. Ear Hear 2010;31:126–33.
[2] Bess FH, Tharpe AM. Unilateral hearing impairment in children. Pediatrics 1984;74:206–16.
[3] Lieu JE. Speech-language and educational consequences of unilateral hearing loss in children. Arch. Otolaryngol Head Neck Surg 2004;130:524–30.
[4] Lieu JE, Tye-Murray N, Karzon RK, Piccirillo JF. Unilateral hearing loss is associated with worse speech-language scores in children. Pediatrics 2010;125:e1348–55.
[5] Kenworthy OT, Klee T, Tharpe AM. Speech recognition ability of children with unilateral sensorineural hearing loss as a function of amplification, speech stimuli and listening condition. Ear Hear 1990;11:264–70.
[6] Reeder RM, Cadieux J, Firszt JB. Quantification of speech-in-noise and sound localisation abilities in children with unilateral hearing loss and comparison to normal hearing peers. Audiol Neurootol 2015;20(Suppl 1):31–7.
[7] Friedmann N, Rusou D. Critical period for first language: the crucial role of language input during the first year of life. Curr Opin Neurobiol 2015;35:27–34.
[8] Bess FH, Tharpe AM. An introduction to unilateral sensorineural hearing loss in children. Ear Hear 1986;7:3–13.
[9] Borg E, Risberg A, McAllister B, Undemar BM, Edquist G, Reinholdson AC, et al. Language development in hearing-impaired children. Establishment of a reference material for a 'Language test for hearing-impaired children', LATHIC. Int J Pediatr Otorhinolaryngol 2002;65:15–26.
[10] Clark JG. Uses and abuses of hearing loss classification. ASHA 1981;23:493–500.
[11] Dunn LM, Dunn LM. Peabody pictured vocabulary test-revised. Circle Pines, MN: American Guidance Service; 1981.
[12] Wechsler D. Wechsler preschool and primary scale of intelligence. New York: The Psychological Corporation; 1967.
[13] Wechsler D. Wechsler preschool and primary scale of intelligence. 3rd ed. San Antonio, TX: Harcourt Assessment, Inc.; 2002.
[14] Wechsler D. The wechsler intelligence scale for children. 4th ed. San Antonio, TX: Harcourt Assessment, Inc.; 2003.
[15] Anne S, Lieu JEC, Cohen MS. Speech and language consequences of unilateral hearing loss: a systematic review. Otolaryngol Head Neck Surg 2017;157:572–9.
[16] Fitzpatrick EM, Gaboury I, Durieux-Smith A, Coyle D, Whittingham J, Nassrallah F. Auditory and language outcomes in children with unilateral hearing loss. Hear Res 2019;372:42–51.
[17] Bess FH, Tharpe AM, Gibler AM. Auditory performance of children with unilateral sensorineural hearing loss. Ear Hear 1986;7:20–6.
[18] Bronkhorst AW, Plomp R. The effect of head-induced interaural time and level differences on speech intelligibility in noise. J Acoust Soc Am 1988;83:1508–16.
[19] Arsenault MD, Punch JL. Nonsense-syllable recognition in noise using monaural and binaural listening strategies. J Acoust Soc Am 1999;105:1821–30.

[20] Shimada A, Udaka J, Nagashima H, Chida I, Kondo E, Nakano S, et al. Effects of FM system fitted into normal hearing ear on speech-in-noise recognition in Japanese school-aged children with unilateral severe-to-profound hearing loss. J Med Invest 2018;65:216–220.
[21] Lieu JEC, Nancy Tye-Murray N, Fu Q. Longitudinal study of children with unilateral hearing loss. Laryngoscope 2012;122:2088–95.
[22] Stewart CM, Clark JH, Niparko JK. Bone-anchored devices in single-sided deafness. Adv Otorhinolaryngol 2011;71:92–102.
[23] Dornhoffer JR, Dornhoffer JL. Pediatric unilateral sensorineural hearing loss: implications and management. Curr Opin Otolaryngol Head Neck Surg 2016;24:522–8.
[24] Peters JP, Ramakers GG, Smit AL, Grolman W. Cochlear implantation in children with unilateral hearing loss: a systematic review. Laryngoscope 2016;126:713–21.
[25] Updike CD. Comparison of FM auditory trainers, CROS aids, and personal amplification in unilaterally hearing impaired children. J Am Acad Audiol 1994;5:204–9.

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