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Comparison of intelligence quotients of first- and second-generation deaf children with cochlear implants

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ABSTRACT

Hearing impairment is a common type of sensory loss in children. Studies indicate that children with hearing impairment are deficient in social, cognitive and communication skills. This study compared the intelligence quotients of first- and second-generation deaf children with cochlear implants. This research is causal-comparative. All 15 deaf children investigated had deaf parents and were selected from Baqiyatallah Cochlear Implant Center. The 15 children with cochlear implants were paired with similar children with hearing parents using purposive sampling. The findings show that the Hotelling trace of multivariate analysis of variance ($F = 6.78$, $p < 0.01$, $\eta_p^2 = 0.73$) was significant. The tests of between-subjects effects for second-generation children was significantly higher than for first-generation children for all intelligence scales except knowledge. It can be assumed that second-generation children joined their family in the use of sign language as the primary experience before a cochlear implant. The use of sign language before cochlear implants is recommended.

1. Introduction

A cochlear implant (CI) will not restore hearing to a normal level but enables a different course of development for cognitive, speech and language functions than would have been possible without the CI [1–3]. The use of CI to restore stimulation to the inner ear has revolutionized treatment for most deaf children. Factors affecting the outcome of pediatric CIs have been the subject of much research. Distinguishing such factors is valuable as it enables researchers to develop more sophisticated CI candidacy criteria and also to develop more effective intervention programs to facilitate auditory, speech and language development of the implantees [4].

Different factors effect the output of a CI; for example, the diagnosis (cause of hearing impairment), age at onset of hearing impairment, age at implantation [5,6], type of implant (number of active electrodes, type of processor) [2], and the anatomical aspects of the cochlea [7]. Studies of both individuals and groups of profoundly deaf children have shown positive effects from the use of CIs on speech perception [8–11], speech production [1,11–14], language development [8,15], social skills [11,16] and quality of life [17]. Cognitive abilities have been implicated as influencing language development after cochlear implantation [18], but this finding has not been universal [19].

An important factor in cognitive and language development of deaf children is the whether or not their parents are deaf. Deaf children born to deaf families have been found to out-perform those from hearing families in terms of intelligence and related abilities [20]. It is assumed that deaf children of deaf parents (DCDP) have early and consistent contact with sign language, while deaf children of hearing parents (DCHP) have contact solely with spoken language if their hearing parents do not communicate with them in sign language [21–23]. DCDP can surpass hearing children of hearing parents having early and consistent contact with spoken language in this respect. In contrast, DCHP tend to have late and insufficient contact with sign language and are thus delayed in the development of some nonverbal spheres of logical thinking such as abstract spatial reasoning [24,25] and understanding the principles of liquid conservation [26].

Deaf children born to hearing families experience delays in oral language and sign language [4,27]. Second-generation deaf children who learn sign language from their parents as their native language from birth are termed “native signers” and perform better in intelligence tests than their deaf peers with hearing parents [24,28,29]. They also show significantly better performance in

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“theory of mind” tasks in comparison with deaf children from hearing families [30–34]. Furthermore, they show better development of a second verbal language and of reading skills when compared with first-generation deaf children [35].

Comparisons of the cognitive features of deaf children raised in deaf families versus those raised in hearing families have been published; however, CI outcomes in these two groups of deaf children have not been compared nor has it been determined if the effect remains after CI. This retrospective study investigated the relationship between parental hearing status and CI outcomes in their deaf children. The intelligence quotients (IQ) of deaf children with deaf parents versus those with hearing parents were compared after CI.

2. Materials and methods

The study group consisted of 15 cochlear-implanted deaf children with deaf parents. This group had the opportunity to acquire Persian sign language from their parents. An equal number of deaf children with normal-hearing parents were selected by matched sampling as a reference group. Participants were matched based on onset and severity of deafness, duration of deafness, age at CI, duration of CI, gender, and implant model. All participants with syndromic deafness and additional disabilities were excluded from the study. Only difference between groups is that second-generation deaf children had deaf parents with which they communicated in sign language but had received no structured training in sign language.

Demographic features of the participants are shown in Table 1. The participants were selected from prelingually deaf children who had undergone CI at the Baqiyatallah Hospital Cochlear Implant Center. All participants had been diagnosed with profound, bilateral, sensorineural hearing loss within their first year of life. All CI children received two sessions per week of auditory verbal therapy for one year. The therapy was presented by experienced speech therapists.

Cognitive functioning was measured using the Stanford-Binet intelligence test (fifth edition) (SB-5) [36]. This is a test of intelligence/cognitive abilities for individuals 2 to +85 years of age (child, adolescent, adult). It is a major revision of the Stanford-Binet intelligence scales: fourth edition (SB-4) [37].

The SB-5 includes 10 subtests selected and designed to measure five CHC factors (fluid reasoning, knowledge, quantitative reasoning, visual-spatial processing, and working memory) within the verbal and nonverbal domains. A global full-scale IQ score is provided in addition to verbal IQ, nonverbal IQ, and five composite factor scores. All scores are based on a mean of 100 and standard deviation of 15 [36].

The standardized sample of SB-5 was stratified to closely match the 1998 United States census data on key demographic variables of geographic region, race/ethnicity, age, and socioeconomic level to generalize the performance of the population. Socioeconomic level was estimated by the number of years of education completed or, in the case of children, their parent's education level. Other technical characteristics, such as reliability (internal consistency, stability, and inter-rater agreement) and validity of SB-5 scores were generally considered positive in two independent reviews [38,39]. Both reviews noted improvements over SB-4, but both also noted some problems. Independent studies have seriously challenged the claim that SB-5 measures five factors using SB-5 standardization data. DiStefano and Dombrowski [40] recognized the problem of not using or reporting the EFA and attempted to rectify this for SB-5 standardization data.

The SB-5 was normalized and adapted by Afrooz and Kamkary [41] for the city of Tehran and it was called the Tehran-Stanford-Binet (TSB5). The test was administered by a professional psychologist with experience working with deaf children, who performed like people with normal hearing because of their improved language perception after CI and one-year rehabilitation program.

Table 1
Demographic characteristic.

	Group	Min	Max	Mean	Std. deviation
Age (mth)	FG	60	96	63.36	24.96
	SG	37	96	77.64	27.95
Age at CI (mth)	FG	24	48	33	25.56
	SG	19	48	32.6	24.72

mth = month, FG = first generation, SG = second generation, CI = cochlear implant.

3. Results

The descriptive characteristics (mean and standard deviation) are shown in Table 2 for both first- and second-generation children with CI and it can be seen that they exhibit differences in their IQ components. Multivariate analysis of variance (MANOVA) was used to examine the differences between groups (Fig. 1).

The assumption of normality was maintained for all variables in the cognitive profile. This means that the intelligence component followed a normal curve and any skewness was not significant. Levene's test for equality of error variance was used to test the results and indicated that the variance from all components of the cognitive profile were equal (Table 3).

Box's M tests were used, which assume that the vector of the dependent variables follows a multivariate normal distribution and the variance-covariance matrices are equal across cells formed by between-subject effects ($F_{21,2574/06} = 5.385$, $p < 0.05$).

The results of MANOVA and the Hotelling trace indicated a difference between groups for at least one dependent variable ($F = 6.78$, $p < 0.01$, $\eta_p^2 = 0.73$). Univariate ANOVA shows that second-generation deaf children acquired higher scores than first-generation deaf children in fluid reasoning, quantitative reasoning, visual-spatial processing, working memory, verbal IQ, nonverbal IQ and full-scale IQ. There was no significant difference between groups in knowledge. It can be said that deaf children with deaf parents have better cognitive profiles than deaf children with hearing parents (Table 4).

4. Discussion

This study compared the CI outcomes of first-generation deaf children versus second-generation deaf children with hearing parents. The findings indicate that deaf children with deaf parents out-performed those with hearing parents. This difference in outcomes occurred despite the fact that all study participants were homogeneous regarding onset and severity of deafness, duration of

Table 2
Descriptive characteristics (mean and std. deviation).

Component	First generation		Second generation	
	Mean	Std. deviation	Mean	Std. deviation
Fluid reasoning	89.53	8.27	99.28	7.51
Knowledge	85.47	9.05	86.14	7.20
Quantitative reasoning	89.87	8.01	96.78	6.60
Visual-spatial processing	92.33	4.19	97.43	6.37
Working memory	89.93	9.18	97.28	4.53
Verbal IQ	91	6.10	96.07	7.04
Nonverbal IQ	93.40	8.39	98.85	6.99
Full scale IQ	92.20	7.09	97.46	6.40

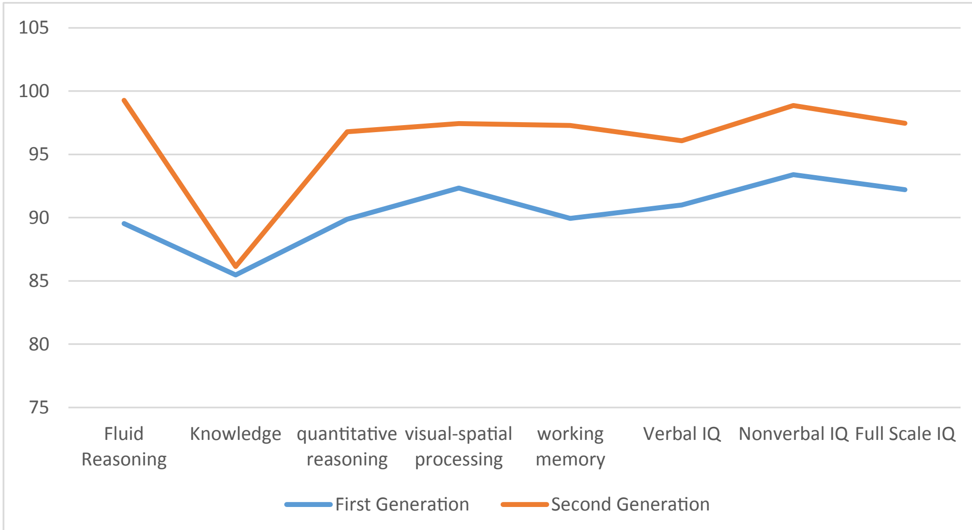

Fig. 1. Results for the IQ profile in deaf children with hearing parents and those with deaf parents.

Table 3
Normality & Levene's test.

Component	Normality			Levene's test	
	Skewness	Z k-s	Sig	F	Sig
Fluid reasoning	0.07	0.48	0.89	0.14	0.70
Knowledge	0.14	0.49	0.96	0.32	0.57
Quantitative reasoning	−0.39	0.67	0.76	0.08	0.77
Visual-spatial processing	−0.18	0.84	0.57	0.11	0.74
Working memory	−0.13	0.62	0.83	0.09	0.76
Verbal IQ	−0.12	0.57	0.89	0.26	0.62
Nonverbal IQ	−0.44	0.52	0.95	0.71	0.41
Full scale IQ	−0.64	0.49	0.97	0.52	0.41

deafness, age at CI, duration of CI, gender, and implant model.

Earlier studies have indicated that deaf children with deaf parents perform better than deaf children with hearing parents on intelligence tests, theory of mind tasks, second language development, reading skills, reaction time and left hemisphere maturation [1,4,10,13,17,20,23,27,28,34,35,42–44]. When the results of the numerous studies summarized above are combined with the findings of the current study, the resulting evidence indicates that deaf children with deaf parents have enhanced communication abilities compared with their peers with hearing parents. This could be related to the earlier onset of communication between deaf children and deaf parents. Deaf parents deal better with the early learning needs of their deaf children than do hearing parents [28,45].

Learning the visio-spatial grammar of sign language improves the visual and spatial skills of deaf children [46]. Exposure to visual communication-promoting strategies begins at birth in deaf families: deaf parents communicate with their deaf child through gestures and signs immediately after birth. Deaf children do not have access to adequate auditory information before CI; therefore, the visual part of communication is critical for them. Deaf parents develop communication with their deaf children using eye contact, facial expression, body language, speech reading and especially sign language. Deaf parents of deaf children can sustain communication in a visual mode, waiting for their child's visual attention to be drawn, in order to communicate. This communication practice is not a natural habit for hearing parents, because they use an aural-visual mode of communication [47]; therefore, deaf children with deaf parents acquire sign language in a natural way.

Earlier studies indicate that the age of first language acquisition can be a determining factor in the success of both first and second language acquisition. Early acquisition of sign language as the child's first language supports later learning of a spoken language [21,48,49].

Table 4
ANOVA for cognitive profile.

Component	SS	df	MS	F	Sig	η_p^2
Fluid reasoning	688.72	1	688.72	35.72	0.01	0.68
Knowledge	9.69	1	9.69	0.19	0.66	0.07
Quantitative reasoning	346.67	1	346.67	25.42	0.01	0.58
Visual-spatial processing	187.99	1	187.99	12.06	0.01	0.41
Working memory	391.45	1	391.45	20.65	0.01	0.53
Verbal IQ	186.34	1	186.34	8.87	0.01	0.34
Nonverbal IQ	215.65	1	215.65	6.50	0.01	0.31
Full scale IQ	200.67	1	200.67	14.07	0.01	0.44

5. Conclusion

These study findings confirm that second-generation deaf children exceed deaf children of hearing parents in terms of CI performance. It can be concluded that encouraging deaf children to communicate by sign language at a very early age before CI improves their ability to learn spoken language and their cognitive ability after CI. It is recommended that future studies compare greater numbers of deaf children with deaf parents versus deaf children with hearing parents when assessing CI outcomes as well as implementation of a longitudinal study.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ijporl.2016.10.005.

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