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Adults Implanted as Children: Long-Term Educational, Occupational, and Speech Perception Outcomes

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Keywords

Cochlear implant · Educational outcomes · Occupational outcomes · Speech perception · Development

Abstract

Introduction: This study investigates factors that relate to long-term educational and occupational outcomes of adults who received cochlear implants (CIs) during childhood. ***Methods:*** A retrospective chart review was conducted on 109 adults who received a CI before the age of 15 between 2000 and 2012 at a US tertiary medical center. Demographic variables, speech perception scores, and educational and vocational achievements were analyzed. Current US Census and Bureau of Labor Statistics data were used for comparison. ***Results:*** The median age at implantation was 2.81 years, and the median age at data collection was 27.30 years. Most subjects were unilaterally implanted (63.3%) and used an oral communication approach (89.0%). Educational outcomes showed that 17% completed a high school diploma or less, and 9% completed an associates or technical degree. Seventy-two percent of the subjects achieved a bachelor's degree or higher, significantly higher than the general US population (37.9%). Occupational outcomes indicated that subjects were employed across various job categories, with a higher proportion in jobs requiring considerable preparation (job zone 4) compared to the general population. There was a significant negative correlation between age at implantation and speech perception scores. Better word recognition scores were also associated with better educational and occupational outcomes. ***Conclusions:*** Adults who received CIs as children demonstrate excellent educational and occupational outcomes, surpassing those of the general US population. Early implantation and the absence of additional disabilities positively influence these outcomes. Continued investigation of nonspeech outcomes and the factors that influence them is essential to provide better support services for future cohorts.

Introduction

Cochlear implants (CIs) have been available for children with severe to profound deafness for over 30 years. However, the vast majority of literature on children's outcomes with CIs is limited to the short or medium term (<10 years post-activation) and generally focus on speech perception [1–3] or adolescents [4–6]. A large population of CI users who were implanted as children have now reached adulthood, providing a unique

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opportunity to examine other outcomes such as educational achievement and employment, as well as the factors that affect these outcomes. Educational achievement and successful employment play an important role in the quality of life, independence, and social lives of CI users [7–10]. Historically, deaf and hearing-impaired individuals with CIs have shown lower education and employment rates than the general population [11, 12], as well as dissatisfaction with education and employment outcomes [13]. However, since the publication of these studies, the average age at implantation has decreased (a factor known to influence outcomes) and the number of educational and occupational support services has increased [14–17]. Therefore, it is important to revisit the question of educational and educational outcomes as well as examine the demographic variables that influence these measures.

Several recent studies outside the USA have reported on educational and occupational achievements for this population. For example, a South Korean study, Ha et al. [18], examined 71 adults unilaterally implanted before the age of 7. The authors found that the college entrance rate for CI recipients (74.6%) was comparable to that of the general population (72.5%). The employment rate was only examined for 42 college graduates, but it was found to also be similar to the general population (62% vs. 65.1%). Better word recognition scores were associated with students who attended mainstream (as compared to specialized) high school programs and attended college. There was no statistically significant effect of word recognition score on employment outcomes, and no other potentially influencing variables were reported on. These findings are similar to earlier studies on smaller groups of adults (e.g., Refs. [13, 19, 20]). In contrast, Illg et al. [21] found that the average educational and occupational achievement levels for adults implanted as children were below that of the general German population. Maternal education was related to higher levels of educational achievement, but no other outcomes variables were reported on. The authors included a wide range of age at implantation (0.4–18.9 years), which may explain the differences in their findings from Ha et al. [18].

While there are little data describing factors influencing educational or vocational outcomes for adult CI users implanted as children, there have been several recent studies on adolescents. Better educational achievement was associated with earlier implantation [22, 23], bilateral implantation [22, 24], lack of additional disabilities [25], and parental involvement [24]. Our literature review failed to find studies directly investigating the factors related to vocational outcomes for adults implanted as children. Illg et al. [21] hypothesized that improved speech perception scores for early implanted CI users would lead to improved educational outcomes and thus might lead to better occupational outcomes.

The primary objective of this article was to investigate the long-term outcomes for adults who received CIs during childhood. Specifically, our first goal was to examine how various influencing variables – such as the age at implantation, the number of implants, the duration of deafness prior to implantation, and the underlying cause of deafness – affect educational attainment, vocational achievements, and speech perception abilities. Our second goal was to explore the correlation between auditory performance, particularly speech perception, and educational and vocational outcomes. Lastly, we will compare the educational and occupational outcomes of these individuals with publicly available data for the same age-group, providing a broader context for understanding the impact of early cochlear implantation on long-term success in the USA.

Methods

This study received approval from our IRB (i19-01517). A retrospective chart review was conducted on adults who received a CI as a child (<15 years of age) between 2000 and 2012. CI surgery was performed at NYU Medical Center, a tertiary academic medical system. Evaluations and programming were performed at the NYU Cochlear Implant Center. This end date was chosen to ensure that all subjects were at least 22 years of age and likely completing (or nearly completing) college. Demographic variables collected included hearing loss history (e.g., age at implantation, hearing loss etiology, duration of deafness, communication modality) and CI details (e.g., manufacturer and electrode, number of implants). Speech perception data included unilateral scores (better ear) for word (CNC; Peterson and Lehiste [26]) and sentence (AzBio quiet and +10 dB SNR; Spahr et al. [27]) tests at the most recent evaluation. All subjects were at least 15 years old and had at least 3 years of CI experience at this time point. These values were chosen to ensure that data were most likely to reflect performance after reaching asymptotic speech perception scores and to ensure that all subjects had sufficient experience completing adult word and sentence recognition tasks. Finally, educational (e.g., highest level achieved, college attended, major) and vocational (e.g., current occupation) information was retrieved from the chart. For some

Table 1. Job zones

Job zone	Description	Examples
1	Little or no preparation needed	Dishwashers, groundskeeping workers, maids
2	Some preparation needed (typically high school diploma)	Orderlies, counter clerks, customer service representatives, security guards
3	Medium preparation needed (typically vocational school or an associate's degree)	Electricians, barbers, court reporters, medical assistants
4	Considerable preparation needed (typically a bachelor's degree)	Real estate brokers, graphic designers, art directors
5	Extensive preparation needed (typically a master's or doctoral degree)	Pharmacists, lawyers, audiologists, veterinarians

subjects, the managing audiologist provided these details. Subjects without at least one speech perception, educational, or vocational data point were excluded. No exclusions were made for subjects with additional disabilities in order to generate a representative sample of outcomes.

Current statistics regarding educational achievement in the USA were retrieved from the US Census Bureau [28]. Table 2, "Educational Attainment of the Population 25 Years and Over, by Selected Characteristics: 2021," was chosen for its similarity to our dataset. Occupations were classified according to the US Bureau of Labor Statistic's 2023 Occupational Profiles [29], which contain 22 different job categories. The US Occupational Information Network (O*NET) "job zones" [30] were used to rank occupational skill levels (see Table 1). Reference data were taken from the 2023 Occupational Requirements Survey [31].

Results

After data collection, 109 subjects were included. Two subjects had no occupational or educational data; 37 subjects had no speech evaluation after the age of 15 (thus n = 72 for speech perception results). At the time of implantation, the median age was 2.81 years (SD: 4.12, range: 0.53–15.66 years). At the time of data collection in 2023, the median age was 27.30 years (SD: 4.41, range: 22.1–40.98 years). The majority (63.3%) were unilaterally implanted; the remainder were bilaterally implanted. Consistent with clinical practice during the 2000s, all bilateral implantations occurred sequentially. The median time between implants was 6.51 years (SD: 3.88, range: 3.39–20.38 years). The majority of subjects were congenitally deaf and used an oral communication approach. Further demographic details are shown in Table 2.

Educational Outcomes

Seventeen percent of the group completed a high school diploma or less education; 9% completed an associates or technical degree. Overall, 58% completed a bachelor's degree, 3% completed a master's degree, 9% completed a doctorate, and 5% had an unknown educational status. Given small numbers of subjects with master's and doctoral degrees, the group was split into two: "bachelor's degree or higher" (including bachelor's, master's, and doctoral degree earners) and "less than bachelor's degree" (including the "high school diploma or less" group and associate/technical degree earners). We examined how different demographic variables related to educational achievement. There was no significant effect detected for age at onset, age at diagnosis, age at CI, sex, or bilateral versus unilateral implantation when comparing subjects with less than bachelor's degree to those with a bachelor's degree or more.

Eight subjects had significant developmental disabilities (e.g., severe autism, Down syndrome) in addition to their hearing losses. All eight subjects were in the "high school or less" educational category, a significant difference from the distribution of educational achievement for those without additional disabilities ($\chi^2 = 22.19$, $p < 0.001$). Educational environment during high school was available for 41 subjects (37.6% of the study sample). For these subjects, 80% were mainstreamed, all with support services. The remaining 20% were evenly split between a school for the deaf and special education/self-contained classrooms. There was no significant difference detected in educational achievement between the group that was

Table 2. Demographic details

Measure	n = 109
Time of onset	63.30% congenital, 3.67% infancy, 7.34% childhood, 25.67% unknown
Etiology of hearing loss	20 family history/genetic, 8 meningitis, 6 prematurity, 5 Mondini, 3 EVA, 2 hypoplastic cavity, 1 Waardenberg, 1 ANSD, 1 Ushers, 1 autoimmune, 1 CMV, 1 rubella, 1 ototoxic antibiotics, 1 infection (unspecified), 57 unknown
Age at implantation, ear #1	Median: 2.81 years, SD: 4.12, range: 0.53–15.66 years
Configuration	Unilateral: 63.30%, sequential bilateral: 36.70%
Implants: ear #1	Cochlear (95.4%), advanced bionics (1.8%), MED-EL (2.8%)
Breakdown by implants and electrodes	CI24: 8 CI24K: 2 CI24M: 49 CI24R CS: 41 CI24R CA: 2 CI24R ST: 2 Clarion I: 1 Clarion II: 1 Med El Combi 40+: 3
Time between implantation (for bilateral subjects)	Median: 6.51, SD: 3.87, range: 3.39–20.38 years
Communication modality	89% oral, 5.5% total communication, 5.5% unknown
Current age	Median: 27.30 years, SD: 4.41, range: 22.1–40.98 years

EVA, enlarged vestibular aqueduct syndrome; ANSD, auditory neuropathy spectrum disorder; CMV, cytomegalovirus; SD, standard deviation.

mainstreamed and the groups that were not. Six subjects had cochlear malformations (e.g., Mondini, hypoplastic cochleae). Their educational achievement was similar to the rest of the study sample as four completed college and two completed high school.

Educational achievement in our sample was compared to US Census data. There was a difference in the proportion in each category between our data and the census data ($\chi^2 = 99.205$, $p < 0.001$). For the census data, 37.9% of the population had attained a bachelor's degree or higher. In our sample, 72.64% did so. A comparison of educational achievement for each level is shown in Figure 1.

Occupational Outcomes

Employment data were available for approximately 50% of our cohort (n = 71). Subjects were employed across nearly every category (18/22), as shown in Table 3. Five subjects reported being unemployed.

Figure 2 shows the difference in distribution across job zones for the US Bureau of Labor Statistics data and our study sample. There was a significant difference between the distribution of job zones between the two groups ($\chi^2 = 50.38$, $p < 0.001$). Specifically, while only 1.5% of our sample was classified at job zone 1 (little or no preparation needed), this represents 38.5% of the sample in the US BLS data. Consistent with the educational outcomes data, our sample had a higher proportion of individuals at job zone 4 (considerable preparation needed [typically a bachelor's degree]) than the US BLS data (45.5% vs. 19.7%). We examined how different demographic variables related to occupational achievement. The group was broken into two subgroups, with job zones 1–3 and job zones 4–5. This roughly equates to the educational split of greater or less than a bachelor's degree and allows for greater statistical power than comparing across 5 separate job categories. As expected, the breakdown of the two education groups (less than a bachelor's degree vs. bachelor's degree or higher) and the two job zone groups was very similar but not identical. There was no significant effect detected for age at onset, age at diagnosis, sex, or bilateral versus unilateral implantation between the job zone subgroups. There was, however, a significant effect of age at implantation (U = 329.0, $p = 0.02$), such that subjects in job zones 4–5 were implanted significantly earlier (median age: 2.82 years) as compared to subjects in job zones 1–3

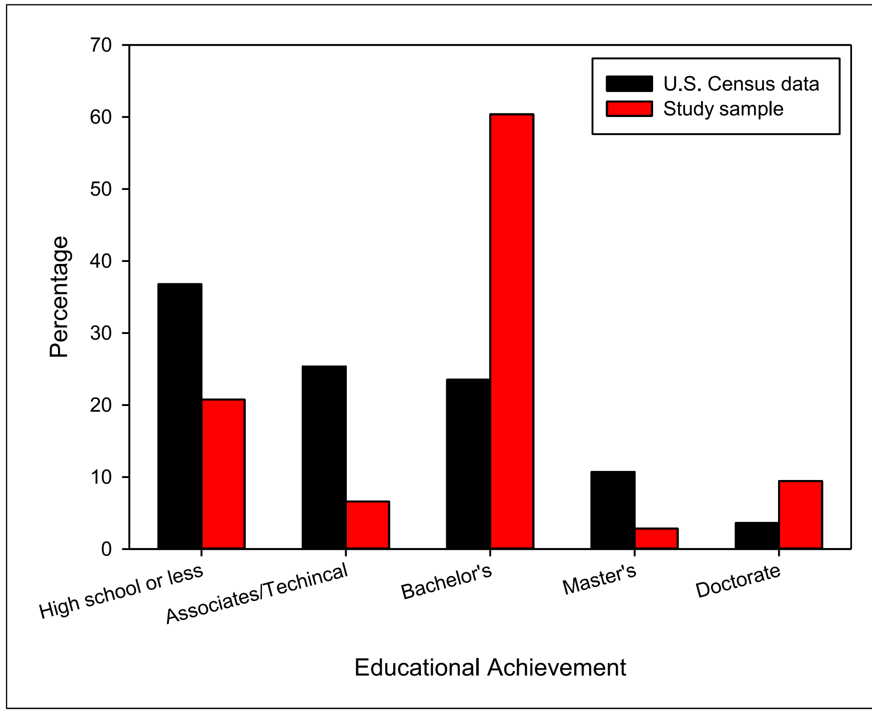

Fig. 1. Educational achievement of our sample (red bars) as compared to US Census data (black bars).

Table 3. Employment data

Profession category	Specific examples
Architecture and engineering (*N* = 2)	Engineer
Arts, design, entertainment (*N* = 2)	Movie director, fashion designer
Building and grounds cleaning and maintenance (*N* = 1)	Janitor
Business and financial operations (*N* = 12)	Recruiter, consultant, finance, accountant
Community and social services (*N* = 2)	Rabbit
Computer and mathematical (*N* = 3)	Software company, information technology
Construction and extraction (*N* = 2)	Construction worker, inspector
Educational instruction and library (*N* = 6)	Teacher, board of education member
Food preparation and serving (*N* = 3)	Culinary worker, baker
Healthcare practitioners and technical occupations (*N* = 9)	Physician, nurse, therapist, anesthetist, psychologist
Installation, maintenance, and repair (*N* = 3)	Mechanic
Legal (*N* = 4)	Lawyer, paralegal
Management (*N* = 6)	General merchandising, marketing
Military (*N* = 1)	Military personnel
Office and administrative support (*N* = 3)	Executive assistant, bookkeeping, inventory
Personal care and service (*N* = 1)	Equestrian trainer
Sales (*N* = 1)	Real estate
Transportation and material moving (*N* = 4)	Truck driver, warehouse employee

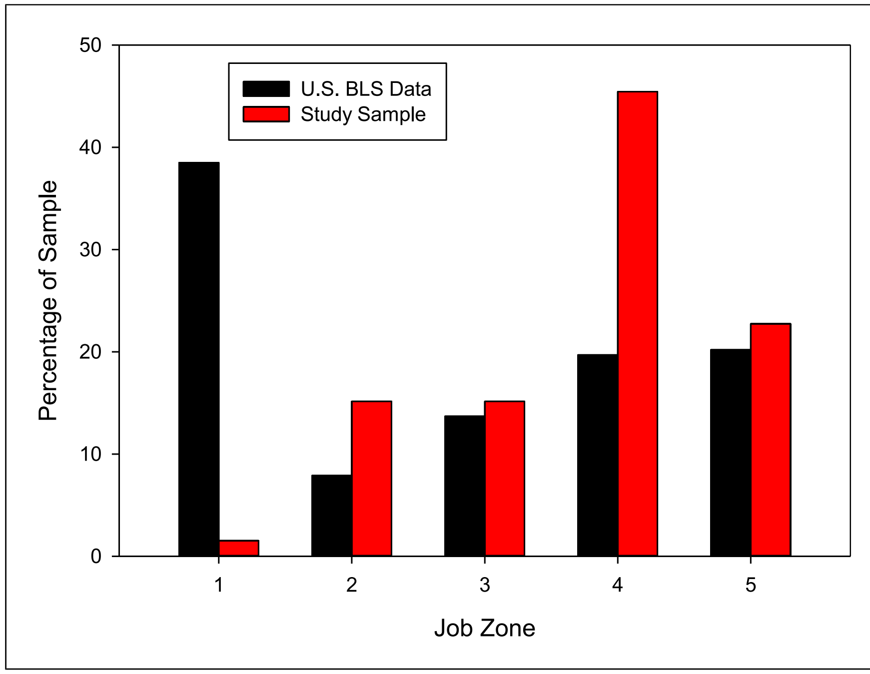

Fig. 2. Occupational outcomes for the study sample (red bars) compared to US Bureau of Labor Statistics data (black bars). See Table 1 for descriptions of job zones.

(median age: 8.19 years). The unemployment rate for our sample (5/71, 7%) is almost double that of the US BLS data (3.7% for 2023, the most recent year available at the time of writing).

Speech Perception Outcomes

Despite a median of 17.5 years of CI experience and reaching at least age 15 at the time of evaluation, we still observed a significant, negative correlation between age at implantation and speech perception scores for CNC words ($r = -0.24$, $p = 0.047$, $n = 68$) and AzBio sentences in quiet ($r = -0.47$, $p < 0.01$, $n = 44$). There was a trend toward a similar relationship for AzBio sentences in noise ($r = -0.28$, $p = 0.08$, $n = 41$) (Fig. 3). There was also a significant negative correlation between the subject's age at the time of evaluation and scores for AzBio sentences in quiet ($r = -0.32$, $p = 0.03$, $n = 44$) and a trend for CNC words ($r = -0.22$, $p = 0.07$, $n = 68$). There were no significant correlations detected between years of CI listening experience and speech perception scores. Bilateral implantation did not beget better speech perception scores.

CNC scores were significantly lower and more variable for subjects with occupations in job zones 1–3 (mean: 68.0% SD: 25.5) as compared to 4–5 (mean: 81.93%, SD: 13.02) ($t = -2.345$, $p = 0.02$, Fig. 4a). There was no significant difference between job zone groups for AzBio sentence scores in quiet or noise. Mann-Whitney tests (due to non-normal distribution of the data) demonstrated that subjects with a bachelor's degree or higher performed significantly better on CNC words ($p = 0.03$, Fig. 4b), but there was no difference in AzBio sentence scores in quiet or noise.

Discussion

This study retrospectively examined educational and occupational achievement for a large group of adults who received CIs as children. These outcomes were compared to normative data for young adults in the USA. Potentially influencing demographic factors, including speech perception scores, were also examined.

To our knowledge, this is the first study to compare educational and occupational outcomes against census data in the USA. In the USA, the Individuals with Disabilities Education Act (IDEA) stipulates that each child is entitled to a "free, appropriate, public education" in the least restrictive environment possible. Since its implementation in 1990, IDEA has resulted in a significant increase in the number of educational supports for children with congenital hearing loss, such as individualized education plans, early intervention services, and specialized personnel. Students in our sample benefited from the provisions of IDEA, though it is difficult to delineate which supports were most beneficial. Still, studies typically find that the deaf population as a whole still has lower rates of

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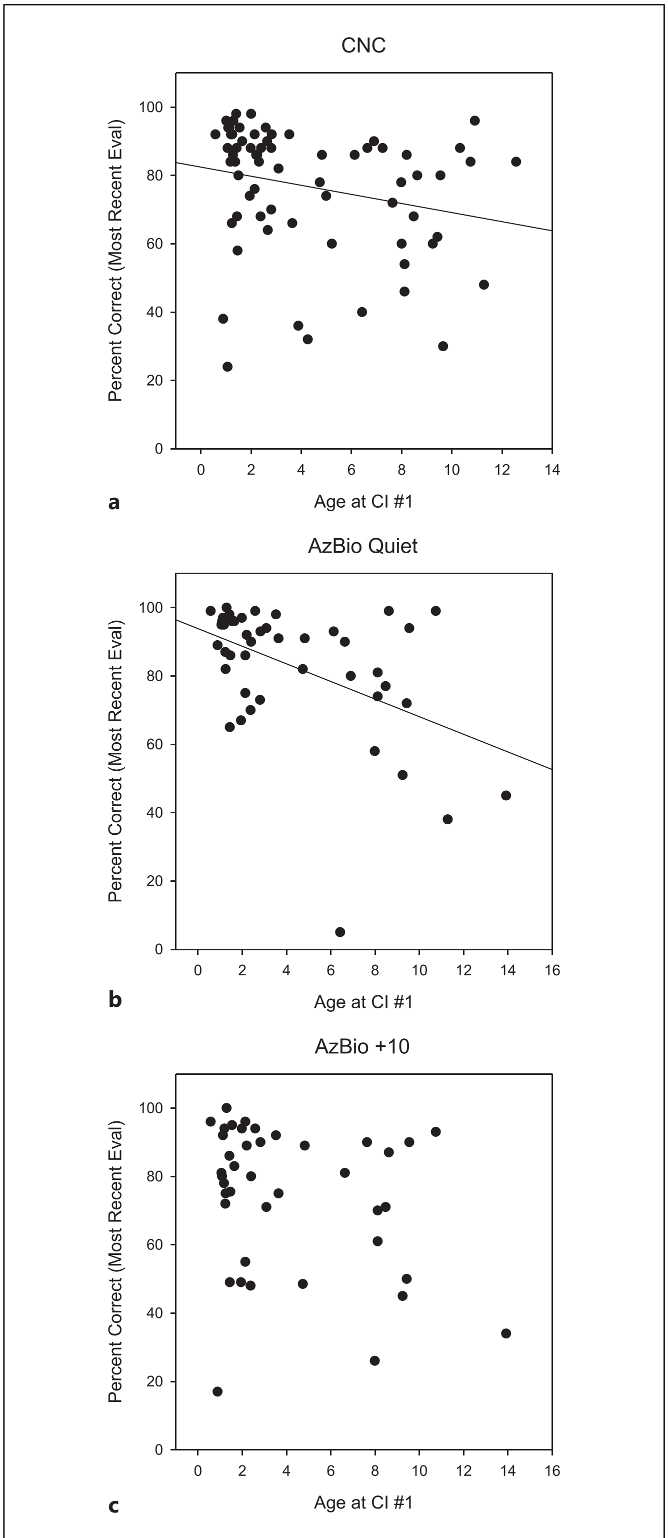

Fig. 3. Age at CI versus speech perception score. Age at implantation (*x*-axis) is plotted as a function of speech perception scores (*y*-axis) for CNC words (**a**), AzBio sentences in quiet (**b**) and AzBio sentences in noise (**c**).

educational and vocational achievement [32]. However, we saw high levels of educational achievement for our subjects, with 70% having achieved at least a bachelor's degree. This study sample was not just equal, but significantly more educated than the general US population of young adults, where only ~38% of the population has achieved a bachelor's degree or higher. US Census data specific to New York state also suggest 38.1% of adults over age 25 have completed a bachelor's degree or higher. Our findings are similar to Ganek et al. [33] who also saw above-average levels of educational achievement. We also saw significantly better occupational outcomes. For example, while 1.5% of our subjects' jobs were classified as job zone 1, this represents 38.5% of the US working population. There are several potential explanations for this discrepancy. First, we expect that use of CIs results in similar performance to normal-hearing adolescents, at least for some subjects [34]. Similarly, adults with CIs have been shown to have similar occupational outcomes as the general population [18]. Second, subjects in our sample are from a major metropolitan area and had access to specialized medical care (i.e., the CI). It is likely they are not a representative sample of the USA. Differences in insurance coverage and family socioeconomic status may have influenced the quality of aural rehabilitation. Still, it is encouraging that academic and occupational performance was at least as good, and in many cases better, than the general population.

We were interested in identifying demographic factors that might relate to educational and occupational achievement. Prior studies with adolescent CI users have found better educational achievement was associated with better speech recognition scores, earlier implantation, bilateral implantation, and parental involvement [13, 22–24]. In our study, the presence of an additional, developmental disability was the only factor significantly related to educational outcomes. As expected, these students were more likely to have lower education levels than subjects without additional disabilities [20, 25]. Methodological differences in how educational achievement is measured and study sample demographics may explain differences between our study and prior research. We did find a significant association between lower age at implantation and better occupational outcomes. As suggested by Illg et al. [21], lower age at implantation is known to relate to better academic skills, which may in turn improve job prospects. However, there are likely many other factors that may explain both younger age at implantation and better occupational outcomes, such as higher maternal education or family socioeconomic status. Our study found an unemployment rate of 7%, almost double that of US data for all eligible workers (3.4%). As of 2017, the

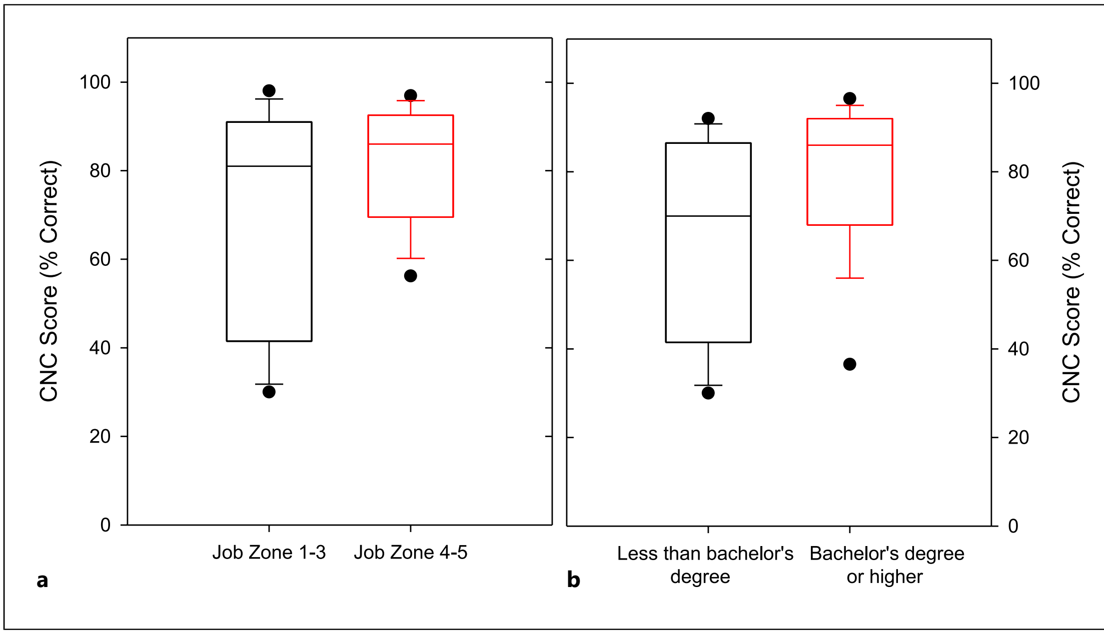

Fig. 4. Occupation and education versus CNC scores. **a** CNC scores were significantly higher for subjects with occupations classified as job zones 4–5 than 1–3. **b** CNC scores were significantly higher for subjects with a bachelor's degree or higher as compared to those with less than a bachelor's degree. Individual points represent the 5th and 95th percentile scores.

official unemployment rate for deaf individuals was 3.8% [32], though this includes all degrees of hearing loss and does not delineate those with or without a CI. Hearing aid use has been shown to significantly reduce the unemployment rate [35]; we lack similar research for those with severe to profound hearing loss, especially adults who received CIs as children. It is important to note that employment data were only available for 50% of our sample; thus, there may be a response bias: because health insurance is often tied to employment in the USA, adults who are unemployed are less likely to return for follow-up CI appointments. Our study sample was also collected immediately following the COVID-19 pandemic, which may have also skewed the unemployment rate.

Speech perception outcomes for adults implanted as children were generally excellent. There was a negative association between age at implantation and scores, suggesting that even many years post-implantation, early implantation is still beneficial. However, these correlations were generally weak, and there are likely many other variables that influence speech perception in CI users. We detected a significant positive relation between both occupational and educational achievement and CNC word scores, implying that better speech perception skills may be at least partially responsible for academic and vocational success. We failed to detect a similar associate for sentence scores, though the reason remains unclear. Other studies have also found better auditory performance (namely, scores on the Categories of Auditory Performance scale) is associated with better academic skills and higher likelihood of mainstream educational settings [21, 36, 37]. However, it is worth noting that good speech perception scores are not necessary for educational success as manual language users can also have excellent and fulfilling educational and occupational outcomes [38, 39].

We anticipate that educational and occupational achievement will continue to grow in future cohorts as the median age at implantation drops and technology improves, both in the device but also in support systems at school or work. For example, artificial intelligence could create faster and more accurate closed captioning services, allowing for greater participation in classroom discussions. There are also now greater opportunities for auditory rehabilitation using telehealth.

Conclusions

Our study showed that adults who received CIs as children achieve excellent outcomes for education, vocation, and speech perception. Compared to the general

US population, the subjects in our study were found to have better educational and occupational outcomes. Additional disabilities were found to negatively affect educational performance, while younger age at implantation was found to positively influence occupational and speech perception outcomes. As the population of adults implanted as children grows, it will be important to continue to assess these outcome measures and the factors that influence them to provide better support services as early as possible.

Acknowledgment

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Statement of Ethics

This study protocol was reviewed and approved by the NYU IRB (i19-01517). Written consent was not required given the retrospective nature of this study.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

E.S. designed the study, analyzed data, and wrote the manuscript. S.W. designed the study. A.L. collected and analyzed data. All authors edited the manuscript and approved the final version.

Data Availability Statement

The data that support the findings of this study are not publicly available due to their containing information that could compromise the privacy of research participants. Further inquiries can be directed to the corresponding author.

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