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Prevalence of Auditory Processing Disorder in School-Aged Children in the Mid-Atlantic Region

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Abstract

Background: Although auditory processing disorder (APD) is a widely recognized impairment, its prevalence and demographic characteristics are not precisely known in the pediatric population.

Purpose: To examine the demographic characteristics of children diagnosed with APD at a tertiary health-care facility and the prevalence of pediatric APD.

Research Design: A cross-sectional study.

Study Sample: A total of 243 children (149 boys and 94 girls) who were referred to the Nemours Audiology Clinics in the Delaware Valley for an APD evaluation. The mean ages were 9.8 yr for boys and 9.7 yr for girls. Out of 243 children referred for an APD evaluation, 94 children exhibited one or more auditory processing deficits in the areas of auditory closure, auditory figure ground, binaural integration, binaural separation, and temporal processing.

Data Collection and Analysis: Demographic and audiological data, clinical history (parental reports on prenatal and postnatal information, birth weight and height, medical and developmental history, otologic/audiological history, education information, behavioral characteristics), and results of the APD test battery were retrospectively obtained from the electronic medical records of each participant. The prevalence of APD was estimated using the total number of students enrolled in the same school attended by each participant in the 2011 academic year as cohort.

Results: The prevalence of APD was 1.94 per 1,000 children in this study. We found that prevalence of APD among the children who attended private schools was more than two times

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higher than the children who attended public schools. The results also revealed that the majority of children referred to the clinics were Caucasian (85.6%), whereas minority groups were underrepresented for this geographical area with only 3.7% of Hispanic or Latino children and 5.8% of Black or African American children.

Conclusions: The estimated prevalence of APD in the current study was lower than the previously published estimates. The difference might be due to the diagnosis criteria of APD among studies as well as the use of school enrollment number as the referenced population to estimate prevalence in our study. We also found a significant difference in APD prevalence depending on the school types. The findings of higher prevalence rates among the children attending private schools and higher proportion of Caucasians children referred for APD evaluation suggest that more children among those in public schools and in the Hispanic and African American groups should have been referred for an APD evaluation. Hence, the current estimate is likely an underestimate of the actual APD prevalence. The low percentage of Hispanic or African American children referred to the clinic for APD evaluations may be related to the socioeconomic status and linguistic differences among the concerned families. The results of this study raise the importance of adapting the APD test battery for children with a different linguistic background as well as increasing awareness of available clinical resources to all families in our area.

Keywords

auditory processing disorder; pediatric audiology

INTRODUCTION

Children with auditory processing disorder (APD) have difficulty understanding speech (especially in degraded listening environments) despite audiometrically normal hearing. The prevalence and demographic characteristics of pediatric APD are still not precisely known. Previous estimations of the prevalence of APD in the general population varied widely from 0.5% to 10% (Chermak et al, 1997; Bamiou et al, 2001; Hind et al, 2011). In children, the reported prevalence is ~3–5%, although some speculate that APD is over-diagnosed (Silman et al, 2000).

One of the likely reasons why different prevalence rates have been reported in the literature is due to the test battery and criteria used to assess and define APD. Although the knowledge regarding APD improved in recent years (ASHA, 2005; AAA, 2010), there is no universally agreed protocol for both its screening and diagnosis (ASHA, 1996). The lack of standardized clinical protocol has been a major obstacle for population-based APD research. However, both ASHA and AAA have published position statement describing recommended diagnostic evaluations of testing (ASHA, 2005; AAA, 2010). There are two standard models of interpretation commonly used for an APD evaluation in the United States, the Buffalo Model (Katz et al, 1992) and the Bellis and Ferre Model (Bellis and Ferre, 1999). These models are primarily based on behavioral testing with specific interpretation profiles and have norms available by age. But in practice, test batteries associated with these models may not be fully used among various service providers. Recommended objective measures such as middle ear muscle reflexes, otoacoustic emissions, and auditory-evoked potentials are used to rule out other hearing disorders, but are rarely employed in the diagnosis of APD itself and there are no yet accepted protocols or normative data for the electrophysiological measurements. Most of behavioral tests are designed for children ≥7 yr (AAA, 2010), which implies that the diagnosis of APD is usually not made until learning deficits are well established. The lack of a universal APD test battery among clinical professionals, both in adults and children, and controversial issues related with terminology and definition of APD might explain the wide range of prevalence published in the past and have posed major challenges in apprehending a population-based prevalence of APD in the United States and internationally.

The purposes of this study are to examine the demographic characteristics of children referred for an APD evaluation at two Nemours Audiology Clinics (Wilmington, Delaware and Newtown Square, Pennsylvania) and to estimate the prevalence of APD among children in the surrounding geographical area. Because the two Nemours Audiology Clinics were the only health-care facilities conducting a comprehensive APD evaluation in Delaware and the surrounding Mid-Atlantic area, we hypothesized that the results of the study would give an accurate estimate of APD prevalence in the studied area.

METHODS

Study Sample

The study included 243 children (149 boys, 94 girls) who were referred to the Nemours Audiology Clinics in the Delaware Valley for an APD evaluation between March 2011 and June 2013 (referral group). Among these 243 children, 94 children who exhibited auditory processing deficits composed the APD group. They were diagnosed with either APD diagnosis or APD weakness following the evaluation. The APD evaluation process at the Nemours Audiology Clinics and the definitions of APD diagnosis and weakness are summarized in “APD Evaluation” below. All children in the APD group exhibited normal tympanometric results and normal-hearing thresholds based on audiometry tested at 0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz. Mean age was 9.76 years (standard deviation [SD] = 2.61) for the APD referral group and 9.70 years (SD = 2.35) for the APD group. Median age was 9 years (interquartile range = 3) in both groups. Age distributions for each group are displayed in Figure 1.

Data

Demographic information, audiological data, clinical history (parental reports on prenatal and postnatal information, birth weight and height, medical and developmental history, otologic/audiological history including previous diagnosis of APD, education information, behavioral characteristics), and the findings of APD evaluation (APD diagnosis and weakness) were retrospectively obtained from the electronic medical records of each participant in the clinical database Epic Hyperspace (Epic Systems Corporation). Study data were collected and managed using REDCap electronic data capture tools hosted at Nemours (Harris et al, 2009) following retrospective institutional review board approval by the institution.

APD Evaluation

The APD evaluation process at Nemours Audiology Clinics is presented in the flowchart in Figure 2. First, all referred children are prescreened during the scheduling process for their insurance coverage, linguistics background (nonnative English speakers are excluded), and possible comorbid diagnoses to ensure that they will be able to complete the required behavioral tests in a reliable manner. Then, an APD intake appointment is scheduled for the children who passed the prescreening. An APD intake evaluation includes a detailed site-specific case history and peripheral auditory evaluation tests (pure-tone and speech audiometry, tympanometry, middle ear muscle reflexes, otoacoustic emissions, and, when necessary, auditory brainstem responses) to rule out peripheral hearing loss and auditory neuropathy spectrum disorder. Children who do not present with a comorbid diagnosis that could potentially interfere with the testing are then fully evaluated with the APD behavioral test battery developed by the Nemours Audiology Clinics based on position statements by AAA (AAA, 2010) and ASHA (ASHA, 2005) to assess the following five auditory processing areas (Bellis and Ferre, 1999):

- Auditory closure: using redundant cues in speech to complete a degraded speech signal (filtered words, fast-rate speech); monaural low-redundancy speech
- Auditory figure ground (AFG): listening to speech in presence of ambient/background noise; monaural low-redundancy speech
- Binaural integration: integrating competing speech signals and being able to repeat them both back accurately; dichotic listening skill
- Binaural separation: separating the simultaneously presented competing signals and selectively repeating only the assigned one back; dichotic listening skill
- Temporal processing: discriminating prosodic differences (pitch, timing, speech contours) that establish phoneme characteristics

Not all children with comorbid diagnosis were automatically excluded from the APD evaluation. Only those who were deemed not to be reliably tested (i.e., with unmanageable attention-related issues, extreme case of anxiety, and language and/or cognitive impairment) were not evaluated using language-based APD test.

The core test battery includes the SCAN-3 (test for APDs in children/adolescents and adults (Keith 2009a; 2009b) and other tests as listed below hereafter. SCAN-3 Filtered Words and SCAN-3 Time Compressed speech to assess the area of monaural low-redundancy speech processing and auditory closure; SCAN-3 AFG and Bamford–Kowal–Bench Sentences in noise test (Bench et al, 1979) to assess the monaural low-redundancy speech processing and AFG; SCAN-3 Competing Words, Dichotic Digits Test (Musiek, 1983), and Staggered Spondaic Words Test (Katz, 1962) to assess dichotic listening and binaural integration; SCAN-3 Competing Sentences for dichotic listening and binaural separation assessment; Frequency Pattern Test/Pitch Pattern Sequence Test (Musiek, 1994) and the Random Gap Detection Test (Keith, 2000) for temporal processing assessment. For Filtered Words subtest, Time Compressed speech subtest, and AFG subtest, stimuli were presented to right and left ears separately. For Competing Words subtest, Competing Sentence subtest, Dichotic Digits

Test, Staggered Spondaic Words, Frequency Pattern Test/Pitch Pattern Sequence Test, and the Random Gap Detection Test, right and left ears were tested simultaneously. For the Bamford–Kowal–Bench test, stimuli were presented to each ear separately as well as binaurally.

In addition to these five auditory processing areas, phonemic awareness was assessed by the Phonemic Synthesis Test (Katz and Fletcher, 1998), and for some cases auditory vigilance was screened by the Auditory Continuous Performance Test (Keith, 1994). For these two tests, stimuli were presented binaurally.

Following the evaluation, children were classified as having an APD diagnosis, an APD weakness, or as being normal. Children with "APD diagnosis" exhibit significantly poor performance on two or more test results for the same APD processing area. Significantly poor performance is defined when a score is 2 SD below the norms provided for each specific test listed above. Children can receive an APD diagnosis in only one auditory processing area or multiple areas. Children with "APD weakness" exhibit an abnormal finding that is not consistently observed in more than one test or a borderline performance (1 SD below the norms) throughout the testing. Children with APD diagnosis could present with an APD in one auditory processing area and another weakness in a different area, but children with APD weakness group only presented with a weakness. Figure 3 displays the distribution of auditory processing deficits in both the APD diagnosis and weakness groups.

Prevalence Estimation

We used the number of children enrolled in schools in the studied area as the referenced population for this study. We did not employ the family address (or zip code) for a few reasons. Because this is a retrospective study, previous family addresses were not always available from the clinical database at the time of the data collection, and the current family address in the database may not be the same address where the studied children actually lived at the time of their APD evaluation. Some children might have lived with their grandparents or close relatives or one of the parents if they were separated. Unlike previous studies study (Chermak and Musiek, 1997), we did not employ the total number of patients in the audiology clinics or the hospital as the cohort because our interest was to estimate the APD prevalence beyond a particular health institute and to obtain a more specific estimate within a particular area. It also avoids a potential sampling bias because a large well-known clinic tends to receive more referrals.

The cohort group consisted of the total number of students enrolled in the same school attended by each participant during the 2011–2012 academic year (we did not exclude the first-grade students from the cohort even though some of the first graders were 6-yr-olds and would not qualify for a complete APD evaluation due to their young age). Enrollment information of all public and private schools in Delaware, Maryland, New Jersey, and Pennsylvania for the 2011–2012 academic year was obtained from the Elementary/Secondary Information System (National Center for Education Statistics, http://nces.ed.gov/ccd/elsi/) on June 2015. The estimated prevalence of APD was calculated by dividing the number of children with current APD diagnosis or weakness by the total number of students enrolled in the same school attended by each participant in the APD group during the 2011–2012 academic year. Because the cohort size was large, we referenced the prevalence rate to 1,000 children instead of 100 children.

Statistical Analyses

Mean and SD were used to summarize the normally distributed data otherwise median and interquartile range were used. To determine group difference with respect to APD, we used χ^2 statistic using the web utility "calculation for the χ^2 test" (Preacher, 2001). In addition, Yates' correction was employed when observed frequencies were <5 (Preacher, 2001). The significance level was set at 0.05 (5% type 1 error tolerance) and all tests were two tailed.

RESULTS

Study Characteristics

Out of 243 participants in the referral group, specific school information was available for 218 participants (90%). The majority of them attended schools in Delaware (40.1%) and Pennsylvania (35.3%), with the rest attending schools in New Jersey (17.9%) and Maryland (6.8%). Eleven children (4.5%) were homeschooled. The distributions of school types (public, private, or home schools) among participants in the four states are summarized in Table 1. This table also lists the results for two sub-types of public schools (assigned and chosen public schools) separately. Chosen public schools include charter schools and schools with special programs such as art. The geographical distribution of children who were referred for an APD evaluation and the two clinic locations are shown in Figure 4. Because private schools and chosen public schools (e.g., charter schools) do not have clear school district boundaries like regular public schools, the number of children was displayed for each county where these schools were located. The figure does not include homeschooling children (n = 11) and children whose attending school information was not available (n = 25). School grade information was available for all the participants except six children. The referral group (n = 243) included 71% attending grades 1–5, 16% in grades 6–8, 8% between grades 9 and 12, 2% in preschools, and 2% with no available grade information. Similarly, the APD group (n = 94) comprised 77% attending 1–5 grades, 16% in 6–8 grades, and only 7% between grades 9 and 12.

APD and School Types

The majority of children (67%) attended public schools in both referral and APD groups. Both groups showed similar ratio for assigned public schools (57.6% and 57.4%, respectively) and chosen public schools (9.1% and 9.6%, respectively). The APD group consisted of slightly higher percentage of children attending private schools (23.4%) than the referral group (18.5%), but the group difference was not significant ($\chi^2 = 1.21$, df = 1, $p = 0.27$). For both APD and referral groups, the percentage of children in private schools were higher compared to the national average of 11.4% (Planty et al, 2009).

Prevalence of APD

Among the 94 children making the APD group, eight cases were excluded from the prevalence analysis because their school enrollment information was not available, as well as two cases of homeschooled children. The remaining 84 APD (24 children with APD diagnosis and 58 children with APD weakness) cases were used to compute an estimated prevalence of APD. The referenced population was based on the 2011–2012 enrollment data of the schools where these 84 children with APD attended. The total cohort group consisted of 40,305 children (including the 84 children in the APD group). The cohort group corresponding to the APD diagnosis subgroup was composed of 17,179 children, and group corresponding to the APD weakness subgroup included 26,524 children (the total of these two cohort groups for the subgroups is .40,305 because some children attended the same schools).

Table 2 shows a summary of prevalence of APD (per 1,000) by APD subgroup. We estimate that 2 per 1,000 children (0.2%) had current auditory processing deficits among the school-aged children in the studied area. The rates were similar ($\chi^2 = 2.46$, df = 1, $p = 0.12$) between the children who exhibited APD weakness (2.2 per 1,000) and the children with APD diagnosis (1.5 per 1,000).

Prevalence of APD and School Type

Detailed information of the prevalence of APD (per 1,000) by school type and APD subgroup can be found in Table 3. Interestingly, the prevalence of APD was more than two times higher in private schools (3.96 per 1,000) than in public schools (1.80 per 1,000), $\chi^2 = 10.30$, df = 1, $p < 0.001$. The same difference between public and private schools was observed among the children diagnosed with APD (3.65 versus 1.29 per 1,000; $\chi^2 = 5.50$, df = 1, $p < 0.02$) and the children who exhibited APD weakness only, but the difference did not reach a significant level for the children with APD weakness (3.37 versus 1.95 per 1,000; $\chi^2 = 3.37$, df = 1, $p = 0.07$).

Study Characteristics: Demographics

Because demographic information was available for all participants, we did not exclude anyone from the demographic analysis. Hispanic or Latino children composed only 3.7% of the referral group and 4.3% of the APD group. These numbers were much lower than the general prevalence of Hispanics or Latinos among the schools included in this study (12%) and the general prevalence (14%) among school children (in public schools) in the studied area based on the Local Education Agency (School District) Universe Survey (Common Core of Data, National Center for Education Statistics).

Both the referral and APD groups consisted of predominantly Caucasian children (85.6% and 87.2%, respectively). African American or Black composed 5.8% of the referral group and 4.3% of the APD group. Similar to the Hispanic demographic results mentioned above, these numbers were much lower than the general prevalence of African American school children in the studied schools (22%) and in the studied area (14.6%).

Slightly more boys (61%) were referred for an APD evaluation than girls. Similarly, more boys (60%) were diagnosed with APD than girls.

DISCUSSION

Previous Estimates of APD Prevalence

The prevalence rate of APD found in this study (0.2%) was lower than the previously reported prevalence of 3–5% in children. The prevalence in the current study was slightly higher but similar to more recently reported prevalence of 0.5% in a large-scale study in the United Kingdom (Hind et al, 2011). The difference may be due to the stringent evaluation process employed at the clinics in this study. The test battery developed by the Nemours Audiology Clinics followed more recent guidelines established by ASHA and AAA (AAA, 2010), which may more accurately differentiate APD from other similar primary disorders as compared to less standardized test batteries. In addition, one to three different tests were used to evaluate each of the five auditory processing areas in the clinical protocol for this study. The APD evaluation in this study may be therefore more sensitive in identifying children who had auditory processing issues.

The difference in prevalence results can also be related to the participant criteria used to define an APD. For example, the UK study by Hind et al (2011) was based on 73 (out of 1,441) children who were referred for hearing or listening problems but had normal audiometric results. However, their estimated APD prevalence includes cases with otitis media with effusion. Only 17 children (1%) in their study were further referred for suspected APD. In the current study, middle ear dysfunction causing peripheral hearing loss at the time of evaluation is a strict exclusion criterion for the APD group. Children with middle ear dysfunction were evaluated after temporary hearing loss was resolved. Another population-based APD study in Poland (Skarzynski et al, 2015) only assessed audiometric and dichotic digit abilities to estimate the prevalence of APD. Hence, we expected our prevalence to be much smaller. On the other hand, the estimated APD prevalence of 2–3% by Chermak and Musiek (1997) was deduced from the available prevalence rates for common comorbid conditions such as otitis media with effusion, learning disabilities, attention-deficit/hyperactivity disorder (ADHD), and the authors' clinical experiences. Furthermore, the higher prevalence rates reported in the literature might be related to higher referral rates in a specific area where a clinic might be well established for years. There are other limitations to our study as discussed in the "Limitation" section. Nevertheless, our current estimate is comparable to the results by Hind et al (2011) in terms of the number of children with APD. As Hind et al (2011) also pointed out, APD is a relatively mild form of hearing disorder and therefore children with APD are less likely to be referred for a full audiological evaluation. This might be one of the reasons that lower APD prevalence rates were found in Hind et al (2011) and the current study.

Limitation

Sampling—Our estimate of APD prevalence is likely to be conservative based on stringent screening criteria and limitations of referral. Even though children were referred for an APD evaluation, many of them were not eligible for full evaluation due to concerns regarding language-related issues including speech and language delays, non-English-speaking patients, cognitive issues, and significant attention and memory deficits in addition to a lack of insurance coverage. Furthermore, although the two clinic locations were the only known pediatric clinics to offer an APD evaluation in the studied area, some children may have been diagnosed with an APD by audiologists in a private practice of which we were unaware of. Also, some children might have been referred to other clinical professionals like speech-language pathologists or behavioral psychologists for learning difficulties because of the lack of other local resources while other children with APD might have not been referred at all. We cannot rule out the possibility that our study did not include all children at risk for APD. In addition, there were some children who did not complete the full APD evaluation due to various reasons (e.g., insurance coverage change, scheduling issues, and other health issues). As a result, the prevalence in the current study is certainly a conservative estimate of APD prevalence.

Comorbidity—Comorbidity is another limitation of the current study. The screening intake provides analysis of a patient's case history including multidisciplinary testing for potential comorbid diagnosis that would prevent APD diagnosis. For example, patients whose record indicated extremely low cognitive function, pervasive developmental delay, or unmanaged attention problems were not assessed using the behavioral test battery because their primary diagnosis and/or underlying language problems would not provide reliable results (Sutcliffe et al, 2006). Some patients who exhibited unmanaged attention problems may not be able to complete a series of tests during 90–120 min. As a result, there were some children who were not eligible or compliant to complete the comprehensive APD evaluation. These unknown APD referrals might contribute to a lower prevalence estimate in this study as well. As for comorbidity among the APD group, some children in the APD group had comorbid disorders such as ADHD, learning disorder (including reading problems), anxiety, etc. However, it is not possible to estimate the actual proportion of these comorbidities in the current study because other evaluation results such as cognitive, neuropsychological, psychoeducation, or speech-language assessments were not always readily available for this study. Because it is documented that APD coexists with other disorders such as language disorders, reading disorders, or ADHD (ASHA, 2005; Sharma et al, 2009), further research on prevalence of comorbidity among children with APD is needed to fully estimate the prevalence of APD.

Inference to the Population Scale Prevalence—The current study used the school enrollment data of the schools for the referenced population. To estimate prevalence based on relatively small samples over a large-size referenced population (i.e., 40,300 students), many assumptions must be made on the students who were not diagnosed with APD in the cohort group. Although we are aware of various limitations as described above, the prevalence rates reported in this study is our best estimate based on available data in the studied area. To make a population level inference on APD prevalence based on the current data, we would need to have data on the number of all APD cases in the region we studied in a similar time frame as the current study. For the different reasons listed above, it is not be possible to make the population level inference from the current study. A large-scale survey at individual schools would be desirable to fully comprehend the prevalence of APD.

Prevalence of APD and School Type

We found that the percentages of participants who attended private schools were higher in both the referral group (18%) and the APD group (23%) compared to the national average (Planty et al, 2009). The National Center for Education Statistics (Planty et al, 2009) reported that ~11% of all elementary and secondary school students were enrolled in private schools in 2007. The percentage of private school enrollment was slightly higher in the Northeast (15%), but the national regional average was still lower than the current results. The difference in private school attendance rates between the national average and the current study suggests that some children attending public schools were not referred for an APD evaluation during the studied period.

A high APD prevalence in private schools might be due in part to a higher socioeconomic status of concerned families. Children who attended private schools are generally from higher income families with parents with a higher education level (Planty et al, 2009). A higher socioeconomic status might play a role in a higher level of awareness of their child's issue, a higher level of knowledge and recognition of APDs and all available clinical and remediation resources, and their accessibility to clinical services. It is quite possible that APD is no more prevalent in public than in private schools, but there is a possibility that parents who can afford private schools may decide to enroll in private schools or even switch from public schools at the first signs of educational difficulty in the hope of obtaining better services for the child such as smaller class sizes. On the other hand, the prevalence in public schools may be underestimated in this study because the families in a lower socioeconomic status might have less or no awareness of APDs and related clinical services.

APD and Ethnicity

We found a low percentage of Hispanic or Latino children among the referral group in this study. Socioeconomic differences between Hispanic/Latino and non-Hispanic/ Latino populations may have played a role in the lower percentage of Hispanic or Latino children who were referred and/or diagnosed with APD. For instance, children covered by Medicaid are less likely to access APD evaluation services because APD evaluation is typically not covered by Medicaid programs in the studied area. In fact, among the uninsured children, the percentage of Hispanic children (15.1%) is higher than non-Hispanic children (6.8%) nationwide based on the US Census Current Population Survey (DeNavas-Walt et al, 2012).

The low percentage of Hispanic children in this study may be partially due to the fact that some children were first excluded from the referral evaluation based on a linguistic screening. Because the behavioral test batteries are currently normed on monolingual English speakers, children who belong to nonnative English-speaking families are currently excluded during the referral process if the primary language spoken at home is not English. The APD evaluation is thus currently lacking tests for children who are bilingual with a primary language that is not English. There has been a significant increase in the number of children who speak a non-English language at home. About 20% of school-aged children in the United States spoke a language other than English in 2008 (Aud et al, 2010), whereas there was only 9% in 1979. During the same period, children who had difficulty speaking English decreased to 5%. Among those children who spoke a non-English language at home,

~71% of them spoke Spanish as the non-English language. To provide the APD evaluation to those non-English-speaking children, there is a pressing need to develop an APD evaluation procedure available in other languages, Spanish in particular, or to have a battery of test that can overcome the language barrier (e.g., digit-based tests, temporal tests). At the same time, because more children in bilingual/multilingual families can fluently speak in English, a language evaluation by a certified speech-language pathologist should be considered in assessing such children to determine their eligibility for full APD evaluation.

CONCLUSION

Despite the limitation of the study, the current study provided an estimated APD prevalence based on a relatively large sample size of children who were diagnosed with APD. The diagnosis criteria of APD in this study were based on multiple auditory tests specifically addressing five auditory processing areas. Strict screening and diagnosis criteria used in our APD evaluation (as compared to Hind et al [2011] and Skarzynski et al [2015]) may explain the lower prevalence rate found in this study. Another reason for the low prevalence rate could be the choice of the cohort group. Instead of using the total number of patients at a specific clinic, the current study used the school enrollment number as the comparing group. To relate with this method, we found a significant difference in prevalence rates between public schools and private schools. This is the first study to reveal a potential health disparity in accessibility to clinical services by looking at relationship between school type and APD prevalence. In fact, APD is still not a well-known hearing disorder among the general public. To fill the knowledge gap between general public and audiologists, we need to promote the awareness of APD to reach out all the children who might have APD. To understand how prevalent APD really is among children, a large-scale study is needed to estimate the prevalence of APD among children in the future. In addition, to provide available clinical services to all children, a test battery for English as a second language speaker and for nonnative English speakers is needed in the future. Furthermore, establishing more objective measures as part of the regular test battery for APD diagnosis such as electrophysiological responses may improve diagnosis recognition and insurance access to reach a wider range of socioeconomic populations.

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Abbreviations:

ADHD	attention-deficit/hyperactivity disorder
AFG	auditory figure ground
APD	auditory processing disorder

ASHA	American Speech-Language-Hearing Association
SD	standard deviation

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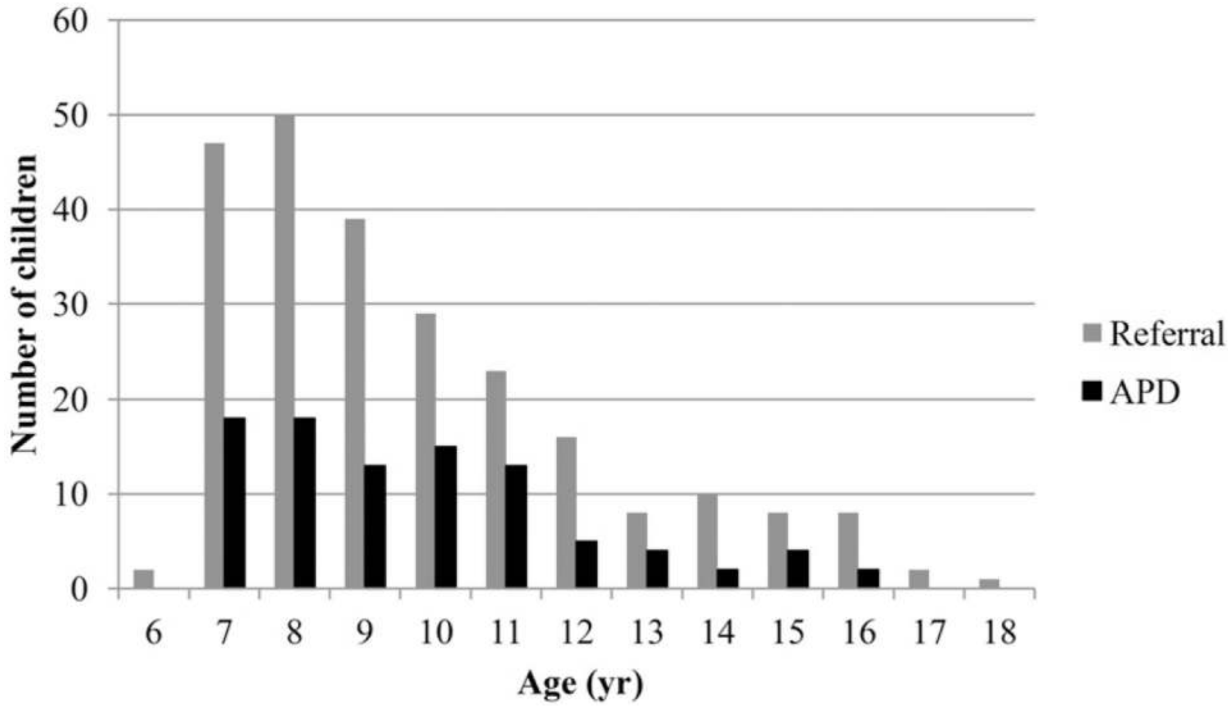

Figure 1.
Age distribution for both referral and APD groups.

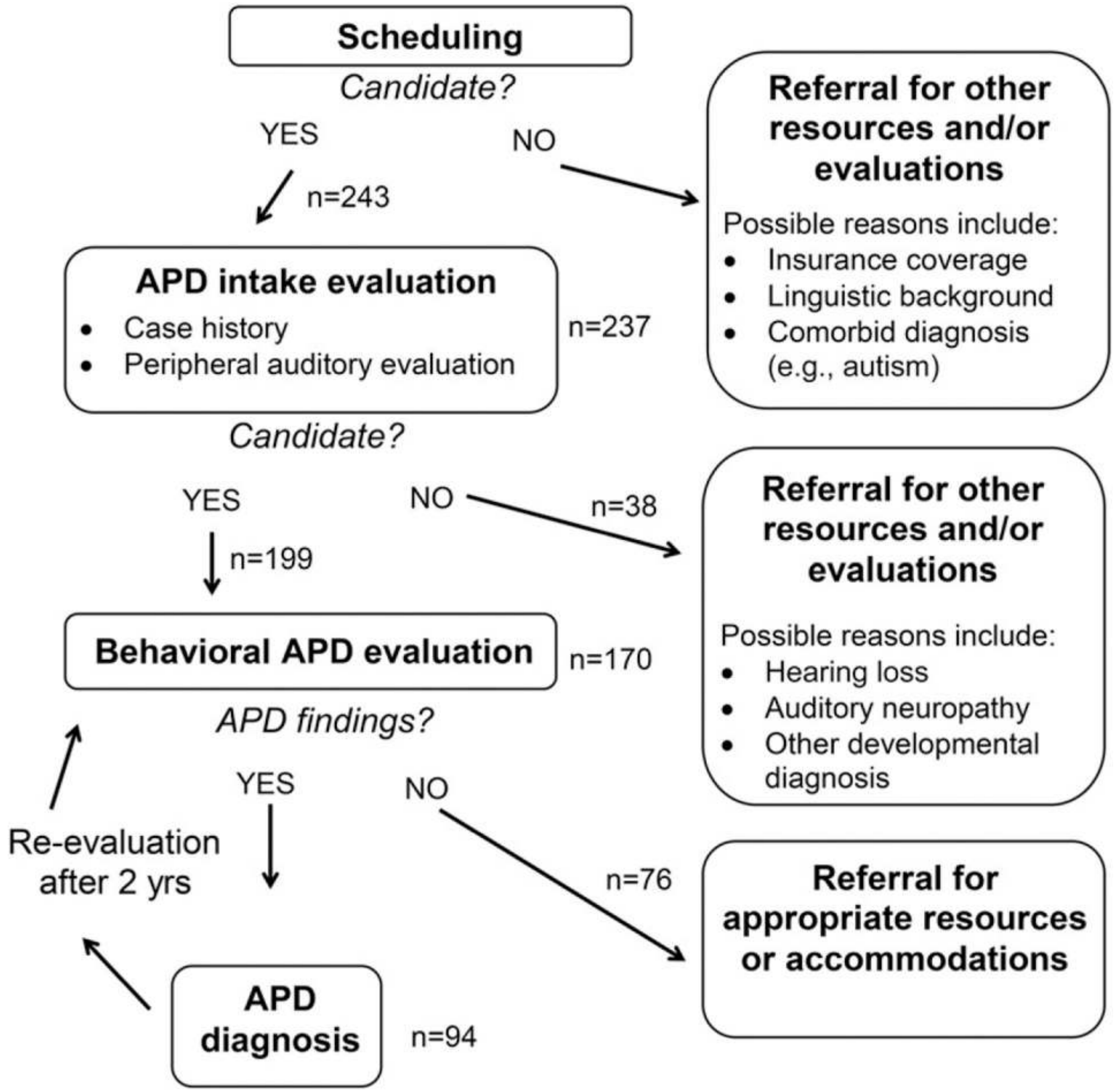

Figure 2.
Flowchart of APD evaluation at the Nemours Audiology Clinics. Cases of no show and pending evaluations are not shown in the chart.

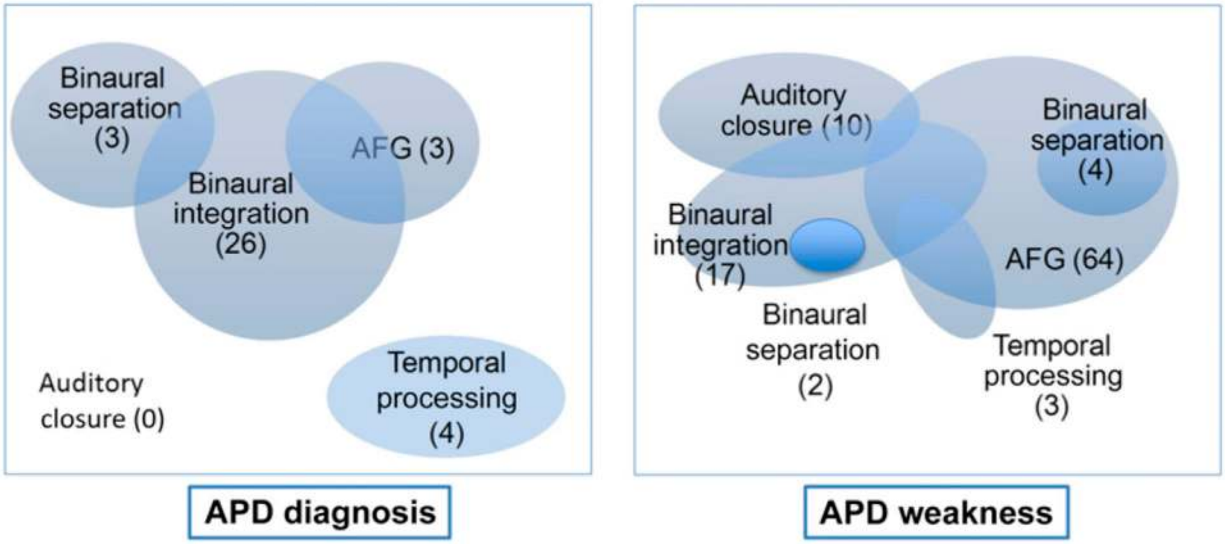

Figure 3.
Distribution of auditory deficit areas of APD diagnosis and weakness in the APD group. Numbers of cases are noted in parenthesis.

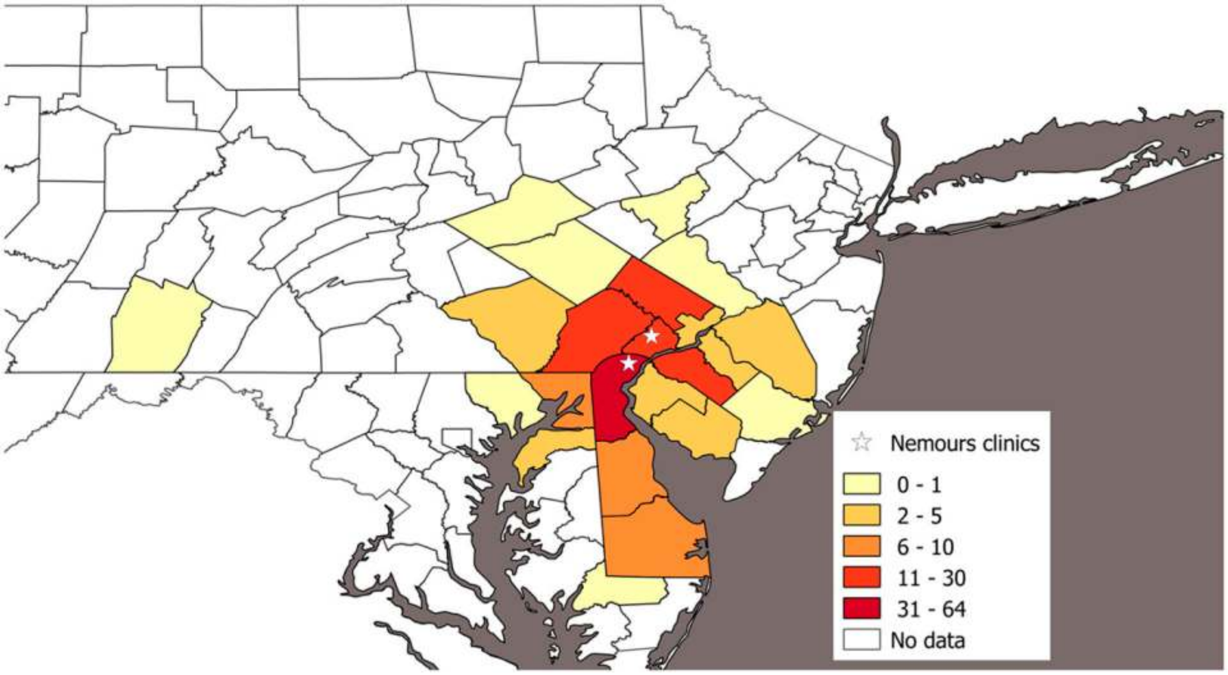

Figure 4.
Geographic distribution of the participants in this study.

Table 1.

Number and Percentage Distribution of APD Referrals by School Type in 4 States

	DE, N (%)	PA, N (%)	NJ, N (%)	MD, N (%)	Total, N (%)
Public assigned	44 (44.9)	51 (59.3)	33 (75.0)	12 (80.0)	140 (57.6)
Public chosen	16 (16.3)	5 (5.8)	1 (2.3)	0 (0.0)	22 (9.1)
Private	23 (23.5)	17 (19.8)	3 (6.8)	2 (13.3)	45 (18.5)
Home school	2 (2.0)	5 (5.8)	4 (9.1)	0 (0.0)	11 (4.5)
Not available	13 (13.3)	8 (9.3)	3 (6.8)	1 (6.7)	25 (10.3)
Total	98 (100.0)	86 (100.0)	44 (100.0)	15 (100.0)	243 (100.0)

Notes: For those who were homeschooled or did not have their school information in the record, their contact address states were used instead of school location. DE = Delaware; MD = Maryland; NJ = New Jersey; PA = Pennsylvania.

Table 2.

Prevalence of APD (per 1,000) by APD Subgroup in the 2011 Academic Year

Characteristic	Rate	Prevalence Ratio
Overall	2.08	–
APD subgroup		
Diagnosis	1.51	Referent
Weakness	2.19	1.45

Note: Prevalence ratio is the ratio of the percentage of children with APD among the subgroup to the percentage of children with APD among the referent subgroup.

Table 3.

Estimated Prevalence of APD (per 1,000) by APD Subgroup and School Type in the 2011 Academic Year

School Type	APD Diagnosis	APD Weakness	APD Total (Diagnosis and Weakness)
Public	1.29	1.95	1.80
Public assigned	1.34	2.03	1.79
Public chosen	0.74	1.66	1.87
Private	3.65	3.37	3.96
Total	1.51	2.19	2.08