

# SYMPTOMS OF AUDITORY PROCESSING DISORDERS (APD) IN CHILDREN WITH TINNITUS

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A Study design/planning  
B Data collection/entry  
C Data analysis/statistics  
D Data interpretation  
E Preparation of manuscript  
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## Abstract

**Introduction:** Children rarely self-report having tinnitus and so there is limited understanding of the problems they face and how tinnitus affects their daily lives. In situations where peripheral hearing is normal and the patient reports difficulty understanding speech, one may consider the co-occurrence of other causes, such as central auditory processing disorders (CAPD). The aim of the study was to assess the presence of CAPD symptoms in children with tinnitus.

**Material and methods:** The study group consisted of 10,582 children 13 years old. The study material included questions about tinnitus experience, screening pure tone audiometry, and the results of the Scale of Auditory Behaviors (SAB), in its Polish adaptation, which was used to assess whether they may have CAPD.

**Results:** In children with tinnitus, symptoms that may indicate CAPD were observed. In 2849 children, an SAB total score of less than 46 was obtained, an indication for an extended diagnosis. Among these same children 33.7% experienced tinnitus. The more frequently a child experienced tinnitus, the lower the mean overall SAB score.

**Conclusions:** Children reporting tinnitus should receive additional diagnostic tests for CAPD. The diagnosis should be multispecialty and, in addition to hearing tests, include an in-depth interview, psychological and pedagogical evaluation, and psychoacoustic tests.

**Key words:** questionnaire • children • tinnitus • CAPD • SAB

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## OBJAWY ZABURZEŃ PRZETWARZANIA SŁUCHOWEGO (APD) U DZIECI Z SZUMAMI USZNYMI

### Streszczenie

**Wstęp:** Dzieci same z siebie rzadko zgłaszają występowanie szumów usznych, stąd zrozumienie nie tylko problemów, z jakimi się borykają, lecz także tego, jak szumy wpływają na ich codzienne życie, jest ograniczone. W sytuacji, gdy słuch obwodowy jest prawidłowy, a pacjent zgłasza trudności ze zrozumieniem mowy, można rozważyć współwystępowanie innych przyczyn, takich jak centralne zaburzenia przetwarzania słuchowego (CAPD). Celem badania była ocena występowania symptomów CAPD u dzieci z szumami usznymi.

**Materiał i metody:** Grupa badana liczyła 10 582 dzieci w wieku 13 lat. Materiał badawczy obejmował pytania o występowanie szumów usznych, przesiewowe badanie audiometrii tonalnej oraz wyniki Skali Zachowań Słuchowych (SAB) w polskiej adaptacji, określającym częstość występowania zaburzeń przetwarzania słuchowego dzieci.

**Wyniki:** U dzieci z szumami usznymi zaobserwowano objawy mogące wskazywać na CAPD. Całkowity wynik SAB poniżej 46, który jest wskazaniem do rozszerzenia diagnozy, uzyskało 2849 dzieci. Wśród tych dzieci 33,7% doświadczało szumów usznych. Im częściej dziecko doświadczało szumów usznych, tym niższy był średni ogólny wynik SAB.

**Wnioski:** Dzieci zgłaszające szumy uszne powinny zostać objęte dodatkową diagnostyką w kierunku CAPD. Diagnostyka ta powinna mieć charakter wielospecjalistyczny i oprócz badań słuchu powinna także uwzględniać: pogłębiony wywiad, ocenę psychologiczną i pedagogiczną, wykonanie testów psychoakustycznych.

**Słowa kluczowe:** kwestionariusz • dzieci • szumy uszne • CAPD • SAB

## Introduction

Tinnitus involves hearing ringing or other sounds, such as roaring or buzzing, from one or both ears. The sounds are internal, and do not have an external source. It may pass over time or in some cases worsen. If it lasts more than three months, it is considered to be chronic.

Tinnitus occurs in both children with hearing loss and those with normal hearing. Possible causes are exposure to loud noise, wax in the ear canal, ear or sinus infection, neck or head trauma, acquired or congenital hearing loss, Meniere's disease, and some medicines (chemotherapy, aspirin, gentamicin, tobramycin) [1]. The symptoms tend to vary depending on the age of the child, and some may be non-specific (such as reports of unusual sounds, distractibility, sensitivity to noise, or anxiety). Diagnosis consists of a physical examination, a thorough medical history, questionnaires, hearing tests, and assessment of the inner and middle ear. If necessary, blood tests or imaging (CT or MRI) may be required. Frontal and temporal areas of the cerebral cortex play a large role in generating tinnitus. Structures belonging to the limbic system – the nucleus accumbens and the reticular nucleus – are responsible for inhibition of tinnitus. If they cooperate appropriately, neural activity of noise is inhibited, and as a result a noise stimulus does not reach the cortex and tinnitus is not perceived [2]. Damage to the lower levels of the auditory system results in reorganisation of the central auditory system, which is why some patients with hearing impairment caused by trauma have tinnitus [2].

Tinnitus is a problem that affects up to one-third of the child population, although the condition often goes unnoticed [3]. Raj-Koziak et al. [4] conducted a study of 43,064 children aged 11 to 13 years and showed that tinnitus affected 3.1% of them. More generally, about 10 to 15% of people suffer from tinnitus. Women and men are equally at risk and the incidence increases with age (at least up to 65 years) [5]. Among the pediatric population, epidemiological data are inconsistent. The study by Rosing et al. [6] among children with normal hearing reported a prevalence of 4.7% to 46%. In addition, central auditory processing disorders (CAPDs) are estimated to affect 2–7% of schoolchildren [7].

In adults, the presence of tinnitus can make it difficult to understand speech. Children, who rarely report tinnitus because they are not fully aware of the problem, are at higher risk of impairment. The general understanding is that when hearing loss and tinnitus occur, there is a diminished supply of acoustic information to the CNS. At the same time, CAPD may be present when peripheral hearing is normal but the patient complains of difficulty understanding speech.

According to the American Speech-Language-Hearing Association (ASHA), CAPD is a condition when there are hearing deficits caused by abnormalities at the level of the CNS, even when the structure and function of the peripheral hearing system remain intact. The causes of CAPD include neurodevelopmental delay, post-traumatic damage, neuromorphological damage, and long-term damage to peripheral hearing.

Children with CAPD are characterised by variable responses to stimuli, lack of auditory attention, auditory hypersensitivity (perhaps with anxiety), difficulty understanding complex commands, and difficulty remembering things that have been delivered verbally. As a result, a child with CAPD has difficulties in functioning properly in everyday life; they have impaired social and emotional development which may later translate into problems in adulthood. The child typically has problems with learning at school; for example, they don't understand what the teacher is saying to them and they are distracted by noises in the classroom. Together, this often means that the child is shy, has low self-esteem, and fails to function well in the environment [8,9].

Since tinnitus and CAPD are associated with pathologies (or alterations) at different locations in the ascending auditory pathway, it has been hypothesised that they may be related [10].

The aim of this study is to investigate the relationship between tinnitus and CAPD in children with normal hearing thresholds. Diges and colleagues conducted a combined study of APD, tinnitus, and HL on the same cohort of adult patients [10]. A similar study was conducted by Raj-Koziak et al. [11] which aimed to evaluate auditory processing abilities in normally hearing adults with and without tinnitus. On the other hand, so far as children are concerned, no studies have been found in the literature on the co-occurrence of tinnitus and CAPD.

## Material and methods

From September to November 2022, a hearing screening program was conducted among elementary school children in Warsaw. The research involved a group of 10,582 children aged 13 years (4891 girls and 4402 boys). The study protocol included screening pure tone audiometry, a questionnaire about tinnitus, and a Scale of Auditory Behaviors (SAB) questionnaire.

All children underwent audiometric screening using the Sense Examination Platform [12,13]. Only air conduction thresholds for 0.5, 1, 2, 4, and 8 kHz were measured. Outcomes were regarded as abnormal if the threshold in either ear was worse than 20 dB at any frequency [14].

**Table 1.** Frequency of occurrence of tinnitus in two groups – normal SAB score (right) and reduced SAB score (left)

|              | Total SAB score     |                     |
|--------------|---------------------|---------------------|
|              | 12 to 45 points     | 46 to 60 points     |
| Never        | 1889 (26.1%)        | 5358 (73.9%)        |
| Rarely       | 567 (41.7%)         | 793 (58.3%)         |
| Sometimes    | 343 (57.1%)         | 258 (42.9%)         |
| Often        | 43 (57.3%)          | 32 (42.7%)          |
| All the time | 7 (70.0%)           | 3 (30.0%)           |
| <b>Total</b> | <b>2849 (30.7%)</b> | <b>6444 (69.3%)</b> |

The children were then asked about the presence of tinnitus. They were asked if they heard humming, squeaking, buzzing, ringing, or other sounds in their ears when the room was quiet, and their answers were scored as 1 – never, 2 – rarely, 3 – sometimes, 4 – often, or 5 – always.

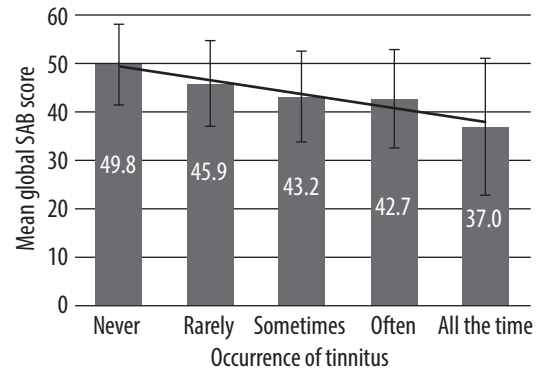
In addition, parents completed the Scale of Auditory Behaviors (SAB). This tool has been validated for Polish at the Institute of Physiology and Pathology of Hearing [15,16]. SAB comprises 12 questions covering symptoms of CAPD, information about the child's schooling, and their social life. The questionnaire reports the frequency of occurrence of CAPD symptoms in the child: if it occurred very frequently it was given a value of 1; almost always, a value of 2; sometimes 3; sporadically 4; and never 5. The values are summed, giving a final score that can range from 12 to 60 points. The lower the score, the higher the severity of CAPD. Scores below 46 points represent a risk of CAPD, and it is then recommended that the child be referred for further CAPD assessment [15,16]. In the classification of Nunes et al. [17], 45–31 points are taken to indicate CAPD risk and 12–30 points the need for a comprehensive diagnosis, and this classification system was used here.

## Results

The first stage of the study was to look at pure-tone audiometry and exclude subjects who had abnormal screening results. Analysis showed that 12.2% of the children tested (1289 subjects) had abnormal audiometry, and these were excluded. The remaining sample then consisted of 9293 children (4891 girls and 4402 boys). Of this number, 2046 students (22.0% of children who passed screening reported tinnitus. Of these, 85 children (4.1%) experienced tinnitus always and often; 601 (29.4%) experienced tinnitus sometimes; and 1360 (66.5%) reported tinnitus rarely.

On the SAB questionnaire, a pass score (60–46 points) was obtained by 6444 students (69.3% of children with normal hearing). There were 2499 children (26.9%) who had a reduced score (45–31 points), and 350 (3.8%) had a score below 30 points.

Breaking the numbers down according to level of tinnitus, the data are shown in **Table 1**. It shows that for those with no tinnitus (7247 children), 26.1% had an SAB total score of less than 46. Among children for whom tinnitus occurred rarely, 41.7% had a reduced score. For those

**Figure 1.** Mean global score on the SAB questionnaire plotted as a function of the frequency of occurrence of tinnitus

who experienced tinnitus sometimes, 343 (57.1%) had a reduced score, and among those who experienced tinnitus often, 57.3% had a reduced score. Finally, for those who experienced tinnitus all the time (10 children), a reduced score was obtained from 70% of them. The clear trend between incidence of tinnitus and reduced SAB score is shown in **Figure 1** and appears to show a significant trend. The more frequently a child experienced tinnitus, the lower the mean overall score on the SAB questionnaire.

## Discussion

This study has demonstrated a clear relationship between the frequency with which a child experiences tinnitus and the presence of CAPD. In school-aged children, those with more frequent tinnitus are more likely to have a low SAB score, indicating an increased chance of having CAPD. For these children, further diagnosis and treatment is recommended, and this is likely to improve their quality of life. Results in this paper are in line with the study done by Raj-Koziak et al. which showed that, in normally hearing adults, the presence of tinnitus tends to be accompanied with auditory processing difficulty [11].

Chronic tinnitus can be caused by either central or peripheral damage. In those with normal hearing, tinnitus reflects heightened spontaneous activity of auditory neurons in the central auditory system (CAS). Children with speech perception difficulties often have no peripheral damage, indicating that CAPD is not solely a hearing loss problem. The exact mechanism remains unknown, but our findings indicate that tinnitus interferes in some way with CAS function. We conclude that tinnitus plays a significant role in reducing auditory resolution and impairing gap detection, in this way creating difficulties in speech perception [18,19].

Fournier and Hébert [20] observed that individuals with tinnitus show impaired gap detection in both low and high background noise environments, again suggesting that the presence of tinnitus obscures gaps. As a possible explanation for our findings, children with auditory associative deficits show marked deficiencies in applying linguistic rules to acoustic signals, possibly due to impaired interhemispheric communication and an impaired ability to register and manipulate multiple linguistic targets.

Most studies have confirmed that peripheral damage together with levels of neuroplasticity in the CAS play a role in the development of chronic tinnitus [18,21]. The majority of tinnitus patients have concentration difficulties.

Although newborn screening programs are effective, they do not detect all children with hearing loss. It is important to assess children during their early school years, since acquired hearing impairments or progressive hearing loss may appear at that stage. Children who have tinnitus often do not mention it unless they are specifically asked [22]. Early identification of a hearing disorder opens the door to appropriate diagnosis, early initiation of therapy, and minimisation of developmental issues. Ultimately, this might translate into proper cognitive, social, and linguistic development.

This paper has shown that in growing children it is important to monitor their hearing, level of tinnitus, and CAPD status, since reduced quality of life has negative implications for mental well-being. If CAPD is diagnosed,

clinicians should provide appropriate guidance in terms of home and school interventions that might reduce the potential educational consequences and help prevent future social, emotional, and communication difficulties.

## Conclusions

This study of 10,582 children aged 13 years has demonstrated a clear relationship between tinnitus and the presence of CAPD. The results show that the more frequently a child experiences tinnitus, the more likely they are to have symptoms associated with CAPD. Identifying such children opens the way for further diagnosis and treatment, and therefore has the potential to improve their quality of life.

Our study has shown that hearing deficits and tinnitus are common among 13-year-old children. Proper diagnosis is important, which is why a screening test among school-age children is recommended as a preventive measure.

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