



Prevalence of tinnitus and hyperacusis in 9–12-year-old children

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Abstract

Objectives To estimate the prevalence of tinnitus and hyperacusis in children aged 9–12 years in Flanders, as well as to explore the associations with hearing abilities and listening behaviours.

Design A cross-sectional survey was undertaken in four different Flemish schools. The questionnaire was distributed among 415 children, with a response rate of 97.3%.

Results The prevalence of permanent tinnitus was 10.5% and of hyperacusis was 3.3%. The hyperacusis prevalence was higher in girls ($p < .05$). Some children reported effects of tinnitus in terms of anxiety (20.1%), sleep (36.5%), and concentration (24.8%). When listening to personal listening devices, 33.5% of the children reported to listen for at least 1 h at 60% or higher of the volume range. Moreover, 54.9% of children stated to never wear hearing protection.

Conclusions Tinnitus and hyperacusis are prevalent in children aged 9–12 years. Some of these children might be overlooked and, as such, not receiving the required follow-up or counselling. Development of guidelines for the assessment of these auditory symptoms in children would help to determine the prevalence numbers with greater accuracy. Sensibility campaigns for safe listening are warranted, as more than half of the children never use hearing protection.

Keywords Tinnitus · Hyperacusis · Prevalence · Children · Safe listening · Noise exposure

Introduction

Tinnitus, also referred to as phantom sound, can be described as ringing, hissing, or polyphonic sounds that are perceived in one ear, both ears, or central in the head [3, 15]. These noises occur without the presence of an external acoustic source [7]. Tinnitus is often a symptom of one or multiple underlying pathologies [12]. Otological disorders

are the most common cause. Tinnitus can have a considerable impact on one's quality of life, as it may alter the sleep pattern and concentration span for example. Moreover, it is highly comorbid with psychological symptoms, such as anxiety disorders and depression, and hyperacusis [11, 13, 16, 22, 24]. This latter symptom is defined as reduced tolerance to sound(s) perceived as normal to the majority of the population or perceived as normal to the person before the onset of hyperacusis [1]. Most studies show a similar prevalence for tinnitus and hyperacusis of approximately 15% in adults [4, 5, 26]. Similarly to tinnitus, hyperacusis is often related to hearing damage [2], but also associations with poor neonatal health have been reported [10]. Neonatal illnesses can have a harmful effect on the auditory neurodevelopment and/or cognitive development and predispose the child to behavioural or emotional complications [25].

Prevalence studies on tinnitus and/or hyperacusis are important to substantiate the impact on the population, as well as to support decisions on resource allocation of potential treatments. However, standard diagnostic criteria to determine these prevalence numbers are missing. Hence, the prevalence numbers are quite diverse due to this complexity

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and inadequacy of terminology and definitions, especially with regards to the prevalence numbers in children [19, 21]. Although, a significant number of children seem to suffer from tinnitus. The prevalence of childhood tinnitus is reported to be between 5 and 46% [23]. A study by Gilles and colleagues reported a prevalence of permanent tinnitus of 18% in high school students in Flanders [9], which is in agreement with a more recent study by Nemholt and colleagues. They found a prevalence of clinically significant tinnitus of 16% in Denmark [20]. A similar study in Sweden found a lower prevalence of 9% [29]. This discrepancy can be partially explained by a different measure [i.e., yes–no question vs. numeric rating scale (NRS)], but also country-dependent differences have to be considered [5]. Hence, these prevalence rates seem to be population, context, and question dependent [23]. The prevalence of hyperacusis in children is also difficult to obtain and data are even sparser compared to prevalence studies of childhood tinnitus. A systematic review by Rosing and colleagues found that the prevalence of hyperacusis lies between 3 and 17% in children and adolescents [23]. Children seem to report tinnitus or hyperacusis rarely spontaneously, but they might admit to it when questioned about it. A study by Knobel and colleagues found that only half of the parents know about their child having tinnitus [17]. However, there might be an over-reporting as children seek to please the questioner [27].

To address these research gaps, the current study aimed to obtain epidemiological data in children. More specifically, the prevalence numbers of tinnitus and hyperacusis in 9–12-year-old children were estimated. A secondary aim was to explore associations with hearing abilities and listening behaviours.

Materials and methods

Study population

A cross-sectional survey in Dutch was undertaken in four different Flemish primary schools. In April 2021, the questionnaire was distributed on paper among the four principals of these schools. A total of 415 pupils from 9 to 12 years of age were asked to fill out the questionnaire during class. Their questionnaires were collected at the schools.

Questionnaire structure

The questionnaire was designed by the authors and adapted after feedback from four children, who completed the questionnaire as a test panel, and two teachers. The adaptations were mostly in terms of readability, comprehensibility, and visualisations. The self-administered questionnaire, consisting of 21 questions, assessed the following items: perception

of temporary and permanent tinnitus and its characteristics, experience of hyperacusis and emotions in relation to tinnitus and hyperacusis (if relevant), hearing abilities, and listening behaviour. In addition, the age and sex of the pupils were collected (see Supplementary Appendix 1). The questions were asked as simple as possible with illustrations where needed.

Tinnitus prevalence and its characteristics (7 questions)

First, the prevalence of a tinnitus experience was assessed by a yes/no question (i.e., do you hear a sound in your ears or head that others do not hear?). If yes, six more questions were asked concerning its characteristics: the type of sound, the loudness of this sound, the frequency of this perception, the related emotions and effects on daily life, the difficulty of concentrating in class due to these sounds and the frequency of ear-covering behaviour when exposed to sounds.

Hyperacusis prevalence (4 questions)

The prevalence of hyperacusis was first assessed by a yes/no question (i.e., are normal sounds sometimes too loud for you or do they cause pain sometimes, while other kids do not seem to bother?). If yes, three more questions evaluated the following: the frequency of this experience, coping with daily sounds and the frequency of avoidance behaviour at the playground.

Hearing problems (3 questions)

To assess the hearing ability and/or otological problems of the children, the following items were evaluated: ability to understand speech in class when only the teacher speaks, ability to understand speech in class when the teacher speaks, but classmates are talking loudly and the frequency of ear infections.

Listening behaviour (7 questions)

The first question of this section asked the way the child most often listened to music (headphones and/or earphones and/or loudspeakers). In case they did not listen to music, they could skip the next three questions concerning listening to music: frequency of listening to music in a week, duration of listening through headphones or earphones in a day, and the used volume. In addition, they were asked how often their parents tell them that they put the volume of the TV too loud. Finally, they were asked how often they go to places with loud noises (e.g., party, sports match) and if they protect their ears when they do so.

Statistical analysis

Data were analysed using SPSS statistical software version 28 (SPSS Inc., Chicago, IL, USA). We performed the Chi-square-tests and two-sided independent *t* tests to compare groups of pupils (e.g., tinnitus or not, hyperacusis or not, age groups, boys vs. girls), depending on the type of the variable. A *p* value less than 0.05 was considered as statistically significant.

Ethics committee approval

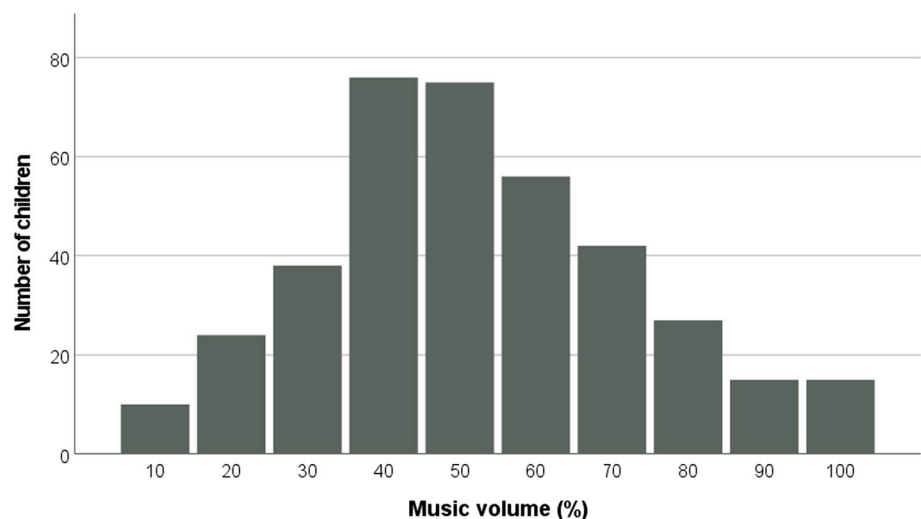
The Committee for Medical Ethics of the Antwerp University Hospital approved this study (B300201630084). The principals of several primary schools were contacted to ask for participation in this study. After a positive agreement, the teachers and parents of the pupils were contacted and informed about the study and the voluntary participation. Pupils were not obliged to fill out the questionnaire. The completion of the questionnaire was considered as a silent approval for participation.

Results

Patient characteristics

The questionnaire was distributed among 415 pupils from 9 to 12 years of age. Eleven children did not fill out the questionnaire correctly and were considered as dropouts. Hence, the response rate was 97.3% (i.e., dropout rate of 2.7%). The study population was evenly distributed in terms of sex (i.e., 202 boys and 202 girls). The mean age was 10.53 (± 0.95 SD) years. More specifically, the sample consisted of 59 9-years-old, 140 10-years-old, 136 11-years-old, and 69 12-years-old.

Fig. 1 Histogram representing the volume (in %) at which the children listen to music



Listening behaviour

A total of 91.5% of the children listens to music. Headphones are used by 53.2%, loudspeakers by 49%, and earphones by 40.5%, and thus, half of the children often use multiple sound sources. Moreover, 43.4% listens to music every day and 38.3% around three times per week. Hence, 81.6% listens regularly to music.

When they listen to music, it is for more than 1 h for 86% of the children. To investigate the potential risk for hearing damage, the children were asked at which volume they played their music (Fig. 1). Volume settings starting from 60% are potentially harmful and 41% of the children exceeds this limit. Taken the loudness and duration of listening to music together, 33.5% of the children listens for at least 1 h at 60% or higher of the volume range. A total of 55% of the children reports that their parents tell them that they set the volume too high.

With regards to going to loud places such as parties or sports matches, 33.1% answered that they go at least once per month to these places, and when they do, 54.9% of children states to never wear earplugs.

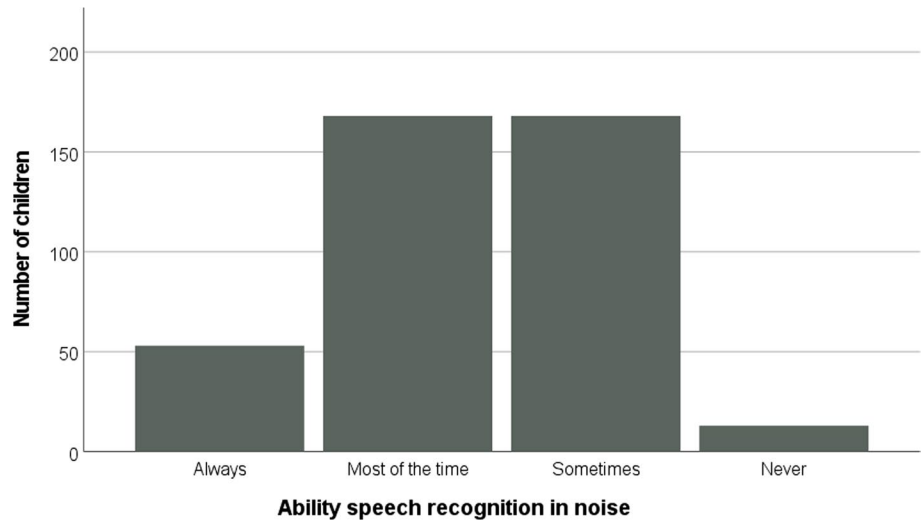
Hearing problems

A total of 4.5% sometimes does not understand the teacher and 3.2% never understands the teacher when classmates are talking (Fig. 2). Moreover, 88% of the children reports to have often an ear infection.

Tinnitus prevalence and its characteristics

A total of 61.8% of the children state that they have perceived a sound in their ears or head that other children did not seem to hear. When they did, 66.1% experienced it as a pure tone and more than half of the children rated the

Fig. 2 Histogram representing the ability to understand speech in a noisy classroom



loudness of that sound from 10 to 30% (Fig. 3). Nevertheless, 22.8% of the children rated that sound at 60% or louder. The tinnitus was permanent in 10.5% of the children.

A total of 49% of the children state in the survey that, when they experience tinnitus, it does not have to affect their behaviour or feelings. However, some children mention that tinnitus makes them feel afraid (20.1%), that it influences their sleep (36.5%), or that it makes it more difficult to concentrate during class (24.8%).

Hyperacusis prevalence

A total of 37.3% of the children answered ‘yes’ to the question if they perceive normal sounds sometimes as too loud or painful, while other kids do not seem to bother. More specifically, 3.3% state to experience this permanently. Figure 4 shows the rating of their tolerance of daily sounds. In 12.9% of the children, the reflex to cover their ears when

there is a sound is present and 9.6% often wants to avoid the playground to avoid this loud environment.

Sex-related discrepancies

The comparison of the responses between boys and girls revealed that boys played their music slightly louder ($\bar{x}_{boys} = 5.6$; $\bar{x}_{girls} = 4.9$; $p < 0.001$), and that they put the TV more often too loud—as noticed by the parents—($p < 0.05$). Nevertheless, this did not result in a higher tinnitus prevalence in boys ($p > 0.05$). On the other hand, the hyperacusis prevalence was higher in girls ($p < 0.05$).

Age-related discrepancies

There are no significant differences between the age groups in the current study and their sound exposure, prevalence of tinnitus, and prevalence of hyperacusis.

Fig. 3 Histogram representing the loudness (in %) of the tinnitus experienced by the children

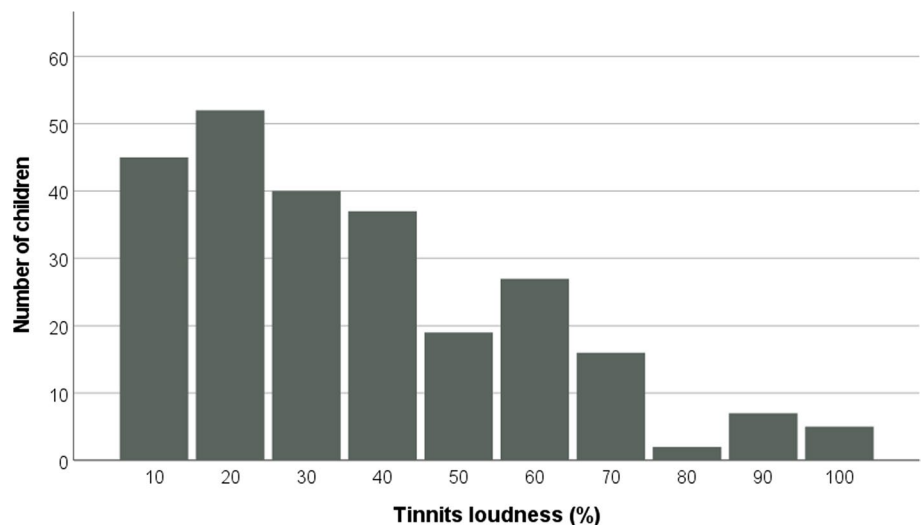
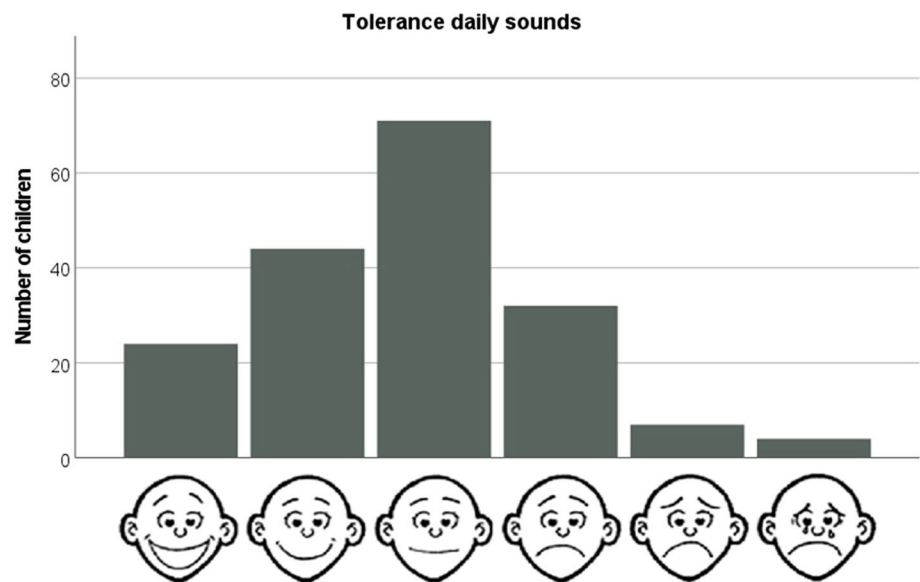


Fig. 4 Histogram representing the rating of the tolerance of daily sounds



Discussion

The main objective of the current study was to determine the prevalence of tinnitus and hyperacusis in children of 9–12 years old in Flanders (Belgium). The effects of these auditory symptoms were questioned, as well as the listening behaviours and hearing abilities in general. Hence, another objective of this study was to investigate if these children were possibly at risk of noise-induced hearing damage.

The survey showed that 10.5% of the children experienced permanent tinnitus. This number is rather low compared to the earlier reported general prevalence of childhood tinnitus (i.e., 5–46%) [23], which could be partly explained by the younger age range in this study. An earlier study in Flanders reported a prevalence of permanent tinnitus of 18% in high school students [9] and it would not be surprising that these adolescents are more often exposed to loud noises and therefore have a higher prevalence of tinnitus.

The prevalence of hyperacusis in this sample was 3.3%. Also, this number is rather low compared to the prevalence found in the systematic review by Rosing and colleagues (i.e., 3–17% in children and adolescents) [23]. The age of our sample might also explain this result, but also the posed question is probably crucial, as 37.3% of the children perceived to be sensitive to sounds sometimes. In addition, 12.9% of the children reported to have the reflex to cover their ears when a sound is present and 9.6% often wanted to avoid the playground to avoid this loud environment. Hence, it seems a good practice to not just ask one question to determine if a participant experiences hyperacusis, but to ask multiple questions to investigate if it is in agreement with the definition.

At the moment of the study, no validated questionnaire to assess tinnitus or hyperacusis complaints in children was

available in Dutch. A validation of the survey, in which consistency of the answers over time is tested, could contribute to the quality and reliability of the data. As such, it is important to determine how to define when a child has tinnitus and/or hyperacusis. While a distinction between temporary and permanent tinnitus was made, a question that could be included in future studies is the duration of the tinnitus perception to eliminate cases with a short duration of tinnitus (i.e., shorter than 5 min). Future studies might consider providing an introductory movie to introduce some difficult terms (e.g., tinnitus, hyperacusis, hearing protection, and speech understanding) and provide information on how to fill out the survey. Moreover, efforts should be made to minimize the recall bias (e.g., asking questions about the last days), as younger is correlated with less recall accuracy [18, 30].

The study sample of the current study experienced a considerable exposure to noise, as one-third went out to loud places and more than half of the children never used hearing protection. Moreover, one-third exposed themselves potentially to too loud noises for too long periods of time. It might be that there is a lack of knowledge with regards to hearing protection and safe listening in this population (and their parents) or that hearing protection is not easily available for them in those situations [6]. Noise-induced hearing loss is a potential risk factor for the development of tinnitus and/or hyperacusis, as well as ear infections. Most children in the current study reported to have had multiple ear infections a year. However, causal relationships between these risk factors and tinnitus could not be proven with the current study.

Besides the influence of otological problems, some gender differences were apparent. First, boys used their music devices at higher signal intensity relative to girls. This finding is in agreement with a study by Warner-Czyz and Cain

[28], who explored the role of gender on acoustic risk-taking behaviours. Second, more girls reported to experience hyperacusis than boys. This corresponds with the previous literature in children and adults [14, 23].

It is important to mention that this study was conducted during the COVID-19 pandemic, and the corresponding social restrictions might have influenced the data. For example, it might be that the percentage of children that go to loud environments is underestimated or that there were higher levels of stress. The latter is known to be associated with tinnitus (please see [8] for a recent scoping review), and as such can influence the found prevalence numbers. While the closing of schools made it difficult to get in contact with principals, the response rate in the four participating primary schools was high (i.e., 97.3%). The participating schools provided regular education in two different regions in Flanders. Future studies should aim to include more schools from different regions to ensure a representative sample.

To conclude, this study indicates that tinnitus and hyperacusis are prevalent among children of 9–12 years old. Some children reported that tinnitus makes them feel afraid, that it influences their sleep, or that it makes it more difficult to concentrate during class. As children are not likely to report this themselves, they might be overlooked and, as such, not receiving the needed follow-up or counselling. Teachers could play an important role to detect red flags, such as listening difficulties and sound avoidance behaviour [20]. Development of validated instruments for the assessment of these auditory symptoms in children would help to determine the prevalence more accurately and reveal underlying aetiologies. As the current study indicates that one-third of the children are exposed to high sound intensities for long durations, sensibility campaigns for safe listening are warranted.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s00405-023-07995-x>.

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Data availability The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request. Data are located in controlled access data storage at Antwerp University Hospital.

Declarations

Conflict of interest No potential conflict of interest was reported by the authors.

Ethical approval The Committee for Medical Ethics of the Antwerp University Hospital approved this study (B300201630084).

References

- Adams B, Sereda M, Casey A, Byrom P, Stockdale D, Hoare DJ (2020) A Delphi survey to determine a definition and description of hyperacusis by clinician consensus. *Int J Audiol*. <https://doi.org/10.1080/14992027.2020.1855370>
- Auerbach BD, Rodrigues PV, Salvi RJ (2014) Central gain control in tinnitus and hyperacusis. *Front Neurol* 5:206. <https://doi.org/10.3389/fneur.2014.00206>
- Baguley D, McFerran D, Hall D (2013) Tinnitus. *Lancet* 382(9904):1600–1607. [https://doi.org/10.1016/s0140-6736\(13\)60142-7](https://doi.org/10.1016/s0140-6736(13)60142-7)
- Bhatt JM, Lin HW, Bhattacharyya N (2016) Prevalence, severity, exposures, and treatment patterns of tinnitus in the United States. *JAMA Otolaryngol Head Neck Surg* 142(10):959–965. <https://doi.org/10.1001/jamaoto.2016.1700>
- Biswas R, Lugo A, Akeroyd MA, Schlee W, Gallus S, Hall DA (2022) Tinnitus prevalence in Europe: a multi-country cross-sectional population study. *Lancet Reg Health Eur*. <https://doi.org/10.1016/j.lanepe.2021.100250>
- Dinakaran T, Deborah RD, Rejoy Thadathil C (2018) Awareness of musicians on ear protection and tinnitus: a preliminary study. *Audiol Res* 8(1):198. <https://doi.org/10.4081/audiores.2018.198>
- Eggermont JJ, Roberts LE (2004) The neuroscience of tinnitus. *Trends Neurosci* 27(11):676–682
- Elarbed A, Fackrell K, Baguley DM, Hoare DJ (2021) Tinnitus and stress in adults: a scoping review. *Int J Audiol* 60(3):171–182. <https://doi.org/10.1080/14992027.2020.1827306>
- Gilles A, Van Hal G, De Ridder D, Wouters K, Van de Heyning P (2013) Epidemiology of noise-induced tinnitus and the attitudes and beliefs towards noise and hearing protection in adolescents. *PLoS ONE*. <https://doi.org/10.1371/journal.pone.0070297>
- Hall AJ, Humphriss R, Baguley DM, Parker M, Steer CD (2016) Prevalence and risk factors for reduced sound tolerance (hyperacusis) in children. *Int J Audiol* 55(3):135–141. <https://doi.org/10.3109/14992027.2015.1092055>
- Hall DA, Fackrell K, Li AB, Thavayogan R, Smith S, Kennedy V, Haider HF (2018) A narrative synthesis of research evidence for tinnitus-related complaints as reported by patients and their significant others. *Health Qual Life Outcomes* 16(1):61. <https://doi.org/10.1186/s12955-018-0888-9>
- Han BI, Lee HW, Kim TY, Lim JS, Shin KS (2009) Tinnitus: characteristics, causes, mechanisms, and treatments. *J Clin Neurol (Seoul, Korea)* 5(1):11–19. <https://doi.org/10.3988/jcn.2009.5.1.11>
- Jacquemin L, Cardon E, Mertens G, Van de Heyning P, Vanderveken OM, Topsakal V, Gilles A (2019) Cognitive performance in chronic tinnitus patients: a cross-sectional study using the RBANS-H. *Otol Neurotol* 40(9):e876–e882. <https://doi.org/10.1097/mao.0000000000002403>
- Jacquemin L, Cardon E, Michiels S, Luyten T, Van der Wal A, De Hertogh W, Gilles A (2022) Hyperacusis: demographic, audiological, and clinical characteristics of patients at the ENT department. *Eur Arch Otorhinolaryngol*. <https://doi.org/10.1007/s00405-022-07336-4>
- Jastreboff PJ (1990) Phantom auditory perception (tinnitus): mechanisms of generation and perception. *Neurosci Res* 8(4):221–254. [https://doi.org/10.1016/0168-0102\(90\)90031-9](https://doi.org/10.1016/0168-0102(90)90031-9)
- Kim YH, Jung HJ, Kang SI, Park KT, Choi J-S, Oh S-H, Chang SO (2012) Tinnitus in children: association with stress and trait anxiety. *Laryngoscope* 122(10):2279–2284. <https://doi.org/10.1002/lary.23482>

17. Knobel KA, Lima MC (2012) Are parents aware of their children's hearing complaints? *Braz J Otorhinolaryngol* 78(5):27–37. <https://doi.org/10.5935/1808-8694.20120005>
18. Macchiarola L, Pirone M, Grassi A, Pizza N, Trisolino G, Stilli S, Zaffagnini S (2022) High recall bias in retrospective assessment of the pediatric International Knee Documentation Committee Questionnaire (Pedi-IKDC) in children with knee pathologies. *Knee Surg Sports Traumatol Arthrosc*. <https://doi.org/10.1007/s00167-022-06922-7>
19. McCormack A, Edmondson-Jones M, Somerset S, Hall D (2016) A systematic review of the reporting of tinnitus prevalence and severity. *Hear Res* 337:70–79. <https://doi.org/10.1016/j.heares.2016.05.009>
20. Nemholt S, Schmidt JH, Wedderkopp N, Baguley DM (2020) A cross-sectional study of the prevalence and factors associated with tinnitus and/or hyperacusis in children. *Ear Hear* 41(2):344–355. <https://doi.org/10.1097/aud.0000000000000759>
21. Nemholt SS, Schmidt JH, Wedderkopp N, Baguley DM (2015) Prevalence of tinnitus and/or hyperacusis in children and adolescents: study protocol for a systematic review. *BMJ Open* 5(1):e006649. <https://doi.org/10.1136/bmjopen-2014-006649>
22. Pattyn T, Van Den Eede F, Vanneste S, Cassiers L, Veltman DJ, Van De Heyning P, Sabbe BCG (2016) Tinnitus and anxiety disorders: a review. *Hear Res* 333:255–265. <https://doi.org/10.1016/j.heares.2015.08.014>
23. Rosing SN, Schmidt JH, Wedderkopp N, Baguley DM (2016) Prevalence of tinnitus and hyperacusis in children and adolescents: a systematic review. *BMJ Open* 6(6):e010596. <https://doi.org/10.1136/bmjopen-2015-010596>
24. Schecklmann M, Landgrebe M, Langguth B, T. R. I. Database Study Group (2014) Phenotypic characteristics of hyperacusis in tinnitus. *PLoS ONE* 9(1):e86944. <https://doi.org/10.1371/journal.pone.0086944>
25. Sheldrake J, Diehl PU, Schaette R (2015) Audiometric characteristics of hyperacusis patients. *Front Neurol* 6:105. <https://doi.org/10.3389/fneur.2015.00105>
26. Smit AL, Stegeman I, Eikelboom RH, Baguley DM, Bennett RJ, Tegg-Quinn S, Atlas MD (2021) Prevalence of hyperacusis and its relation to health: the busselton healthy ageing study. *Laryngoscope*. <https://doi.org/10.1002/lary.29768>
27. Stouffer JL, Tyler RS (1990) Characterization of tinnitus by tinnitus patients. *J Speech Hear Disord* 55(3):439–453. <https://doi.org/10.1044/jshd.5503.439>
28. Warner-Czyz AD, Cain S (2016) Age and gender differences in children and adolescents' attitudes toward noise. *Int J Audiol* 55(2):83–92. <https://doi.org/10.3109/14992027.2015.1098784>
29. Widén SE, Erlandsson SI (2004) Self-reported tinnitus and noise sensitivity among adolescents in Sweden. *Noise Health* 7(25):29–40
30. Zonneveld LN, McGrath PJ, Reid GJ, Sorbi MJ (1997) Accuracy of children's pain memories. *Pain* 71(3):297–302. [https://doi.org/10.1016/s0304-3959\(97\)03379-4](https://doi.org/10.1016/s0304-3959(97)03379-4)

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