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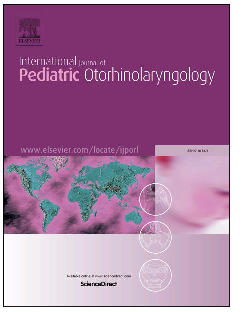

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Dr. Sabarinath Vijayakumar, Dr. A.U. Ahmmed

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A Retrospective Study of Audiological Characteristics of Hyperacusis versus Misophonia in Children with Auditory Processing Disorder.

Dr. Sabarinath Vijayakumar[1] & Dr. A U Ahmmed[1]

Address for correspondence:

Dr. A U Ahmmed

Consultant Paediatric Audiovestibular Physician

Fulwood Audiology Clinic

4 Lytham Road, Fulwood, Preston, PR2 8FH

United Kingdom

Email: aahmmed@hotmail.co.uk

[1] Lancashire Teaching Hospitals NHS Foundation Trust, United Kingdom

Abstract

Objectives

This study aimed to evaluate in children with developmental auditory processing disorder (APD):

1. The value of routine audiological evaluations in distinguishing hyperacusis and misophonia
2. The prevalence and association of tinnitus with the audiological characteristics of hyperacusis, misophonia and no decreased sound tolerance (DST).
3. The association between past history of otitis media with effusion (OME) and DST.

Study Design

Retrospective study comparing outcomes of pure-tone thresholds from .25 to 12.5 kHz, ipsilateral stapedial reflex thresholds (SRTs), uncomfortable loudness levels (ULLs), past history of OME and tinnitus between those with and without DST.

Study Sample

The study included 278 children with a diagnosis of APD, aged 6–16 years (mean age: 11.68 years, SD: 2.21) with nonverbal IQ ranging from 80 to 128 (mean: 98.74, SD: 9.92). Three groups of participants included i). Hyperacusis only (n = 107), ii). Misophonia with hyperacusis (n = 35) and iii). No DST (n = 136).

Results

The pure-tone average for 8, 10 and 12.5 kHz (High PTAvg) was lower than the .25, .5, 1, 2 and 4 kHz pure-tone average (Low PTAvg) in all the three groups in both the ears, with significantly larger High-Low PTAvg difference in the 'Misophonia with hyperacusis' group compared to the 'No DST group in the right ear. SRTs elicited by 1 and 4 kHz tones were similar in all the groups. ULLs were significantly lower for both 1 and 4 kHz tones in both 'Misophonia with hyperacusis' and 'Hyperacusis only' groups compared to the 'No DST' group, with higher level of significance for 4 kHz ($p<.001$) compared to 1 kHz ($p <.01$). ULLs did not reflect the severity of impact of DST on daily life. Despite higher prevalence of misophonia in females, the frequency of significant impact was similar in both males and females. Males had higher prevalence of hyperacusis but the frequency of significant impact on life was more in females.

Tinnitus prevalences were 30.47%, 45.7%, and 18.18% in the 'Hyperacusis only', 'Misophonia with hyperacusis', and 'No DST' groups respectively. The 'Misophonia with hyperacusis' group was older than the other two groups irrespective of tinnitus. Tinnitus was more prevalent in older children in the 'Hyperacusis only' and the 'no DST' groups. The presence or absence of tinnitus did not influence any of the audiological characteristics in the 'Hyperacusis only' and the 'Misophonia with hyperacusis' groups. Participants with tinnitus in the 'No DST' group had significantly lower ULL at 4 kHz, with a significant difference between 4 and 1 kHz in their right ear compared to those without tinnitus.

The prevalences of past OME history were similar in the three groups.

Conclusion

Routine audiological evaluations cannot differentiate between misophonia and hyperacusis. Normal SRTs and low ULLs in DST and in those with tinnitus without DST indicate that higher order brain networks influence ULL, suggesting a need of evaluation for DST in children presenting with tinnitus. The higher high frequency sensitivity in the right ear needs further exploration. The study indicates that DST is unrelated to previous OME history. The study suggests that DST and tinnitus need to be considered as auditory disabilities in addition to different types of listening difficulties in APD.

A Retrospective Study of Audiological Characteristics of Hyperacusis versus Misophonia in Children with Auditory Processing Disorder.

Introduction

Decreased sound tolerance (DST) is a common symptom seen in children referred to paediatric audiology clinics, where children show heightened sensitivity to everyday sounds. These sensitivities can manifest in various forms, including hyperacusis, misophonia, and phonophobia, each presenting unique challenges for diagnosis and treatment. However, the lack of clarity surrounding these conditions, particularly in terms of their definitions, characteristics, and evaluation, often complicates the clinical approach (1–4). The overlap in symptoms between these conditions, combined with inconsistent terminology in the literature, underscores the need for a more nuanced understanding, particularly in children, where such disorders can significantly impact quality of life (5).

Distinguishing between hyperacusis and misophonia is being viewed as an important research agenda in audiology (4,6,7) and for this effort it is important to establish consensus based on clinical evidence. There are differing views on misophonia, if it is a psychiatric disorder related to "hatred" to specific sounds of any origin, or to sounds associated with chewing or eating (mastication rage), or to different human generated sounds in addition to chewing and eating (3,4,8–10). The distinction between hyperacusis and misophonia has been limited to the trigger sounds and emotional responses (3,8,9,11). Ahmmed and Vijayakumar (2024) suggested that one approach to clarify the characteristic features is to start from a very simple definition and then add additional qualifications as new evidence are established; misophonia considered as oversensitivity to sounds of eating and chewing, while hyperacusis viewed as DST to sounds other than chewing and eating (3). The above simple definition of misophonia was based on existing studies (8,9). The findings by Ahmmed and Vijayakumar (2024) in children diagnosed with developmental auditory processing disorder (APD) were generally consistent with the literature on misophonia and hyperacusis (3). The above study highlighted, firstly, misophonia co-exists with hyperacusis in about 97% of cases; secondly, misophonia (with or without hyperacusis) was more common in females and in older children; thirdly, oversensitivity to other body-generated sounds such as coughing, sneezing/sniffing, and repetitive sounds like clicking and tapping were common in misophonia; fourthly, predominant emotional responses in misophonia included disgust and verbal aggression, in contrast to fear and being upset in hyperacusis.

In addition to defining hyperacusis based on types of sounds and emotional responses, some authors proposed various cut-off values of uncomfortable loudness level (ULL) (12). This is likely based on the understanding that hyperacusis is related to the physical characteristics of sounds, such as sound intensity (4,11). ULL cut-offs for diagnosing hyperacusis range from 60 dB HL to less than 100 dB HL. Jastreboff and Jastreboff (2014) indicated that in adults ULLs range between 60-85 dB HL in hyperacusis, and 30-120 dB HL in misophonia (11). It is unclear if participants with misophonia in the above study also had hyperacusis. This distinction matters because misophonia can exist with or without hyperacusis, and these groups may have different audiological characteristics, which this study addresses.

The reliability of ULL as an indicator for DST is debatable (1,13,14). In contrast to the subjective nature of ULL, stapedial reflex measurement has been suggested as an objective measure. The stapedial reflex assesses the integrity of certain parts of the auditory pathway, and dysfunction in this auditory reflex has been associated with DST, although it is not widely utilized in its clinical evaluation (15–17). Notably, this acoustic reflex was not even mentioned in a recent systematic review that examined various clinical assessment for hyperacusis (18). Among the one hundred patients with hyperacusis reported by Anari and colleagues (1999), only fifty-one had their stapedial reflex thresholds (SRTs) measured (19).

Other audiological measures, in addition to ULL and SRT, have been employed to evaluate DST, given that auditory sensitivity is often better for high compared to low frequency tones (12,20). Aazh et al. (2022) identified significant differences in the slope between 8 and 1 kHz pure-tone thresholds and ULLs in patients with misophonia compared to controls, without interaural differences (12). However, there is no such information available for children with DST and normal hearing thresholds. It remains unclear how high-low frequency slopes for pure-tone thresholds and ULLs relate to those for SRT. While SRTs typically cover .5-4 kHz tones, ULLs have been measured and reported for a larger number of frequencies. The measurement of SRT and ULL should be limited to a minimal number of frequencies based on clinical necessity to avoid any distress in individuals with DST (20,21). In the APD clinic conducted by one of the authors, SRT and ULLs are measured for 1 and 4 kHz tones. This study aims to differentiate hyperacusis and misophonia based on audiometric thresholds, SRT, ULL, and their slopes (difference in the absolute values between high and low frequency tones) in children with APD.

Tinnitus is frequently observed in individuals with DST (11,12,22) including children diagnosed with APD (3). However, there is limited information on how different audiological measures related to DST vary with the presence or absence of tinnitus in children with APD. This is another issue that is explored in this study.

Otitis media with effusion (OME), also referred to as glue-ear, is a common childhood condition causing fluctuating conductive hearing loss. This condition typically resolves on its own without causing long-term effects on speech and language development (23). Some studies suggested a link between DST and history of OME (24–26), but there is limited research to confirm this association. Another objective of this study was to investigate DST in children who had experienced temporary conductive hearing loss due to OME in early childhood but had normal hearing thresholds before diagnosis of APD.

Method

Study Design

This retrospective study was conducted as part of a quality improvement project, registered with the clinical audit department at a regional teaching hospital in the Northwest of the United Kingdom. Data were gathered retrospectively from the medical records of children diagnosed with APD within an established clinical service in the tertiary paediatric audio-vestibular medicine department between January 2021 and December 2022. Ethical approval was not required for this study.

Participants

The data used in this study were from 278 out of 279 children with APD that was reported earlier (3). Of the participants in the 'misophonia with or without hyperacusis' group in the above study, only one child had misophonia without hyperacusis. The data of this single child was excluded from the current study. The current study included 159 males and 119 females, diagnosed with APD, aged between 6 and 16 years (Mean = 11.68 years, SD = 2.21) with nonverbal intelligence quotient (NVIQ) ranging from 80 to 128 (Mean = 98.74, SD = 9.92), as measured by the fourth edition of 'Test of Nonverbal Intelligence' (TONI-4) (27). All the participants were healthy English-speaking children attending mainstream schools.

Three groups of participants included in the study were:

Group I. ‘Hyperacusis only’, N=107, comprised of 66 males and 41 females, aged between 7 and 16.33 years (mean = 11.28, SD = 2.17) with NVIQ ranging from 80 to 127 (mean=99.44, SD 10.1).

Group II. ‘Misophonia with hyperacusis’, N= 35, included 11 males and 24 females, aged between 7.91 and 16.75 years (mean = 12.67, SD 2.42) and NVIQ varied from 84 to 128 (mean = 97, SD = 10.58).

Group III. ‘No decreased sound tolerance’ (No DST), N= 136, had 82 males and 54 females, age ranging from 6.91 to 16.5 years (mean = 11.73, SD = 2.11) with NVIQ between 81 to 125 (mean = 98.65, SD = 9.61).

Structured history questionnaire in evaluating APD and DST

A structured clinical history questionnaire is routinely employed for the assessment of APD. It includes detailed queries about sensitivity to sounds, other sensory symptoms, auditory symptoms, perinatal history, behaviour, developmental milestones, educational progress, family history, and medical conditions (3,28,29). The caregiver fills out the questionnaire, which is subsequently assessed by the clinician with contributions from both the caregiver and the child during the clinical consultation. The information is subsequently stored in the clinic record. The response choices about the question about the presence or absence of oversensitivity to sounds included ‘Never’, ‘Occasional’, ‘Most times’ and ‘Always’. Participants who report oversensitivity to sounds have the option to select from thirty-seven common sounds that may serve as triggers. These include sounds related to chewing and eating, which form the basis for diagnosing misophonia (3,8,9). An option for specifying any other sounds not listed in the questionnaire is also included. In this study, children with responses of ‘Always’ or ‘Most times’ were classified as having Decreased Sound Tolerance (DST). Children with responses of ‘Never’ or ‘Occasional’ oversensitivity to sounds were considered not to have DST (No DST). Additionally, the questionnaire explored how DST impacted daily activities, with response choices that included ‘Not sure’, ‘No restriction’, ‘Little impact’, ‘Moderately’, and ‘Severely’. For the purpose of the current study, the responses of ‘Not sure’, ‘No restriction’ and ‘Little impact’ were considered as ‘non-significant impact’, and the responses of ‘Moderately’ and ‘Severely’ were considered as ‘significant impact’. Such an approach is similar to that seen in some publications (30–33). Different emotional and behavioural responses to sound triggers, important in distinguishing between hyperacusis and misophonia, are also recorded within the questionnaire which have been published previously (3).

The history questionnaire also enquired about the presence or absence of tinnitus and past history of OME.

Hearing Thresholds

Consistent with the routine practice in the department, the participants had their pure-tone audiometric thresholds measured using a PC-controlled AURICLE Aud audiometer (GN Otometrics), operated via the OTOsuite Audiometry Module software. Sound stimuli were delivered using Sennheiser HDA 300 headphones at frequencies of 0.5, 1, 2, 4, 8, 10, and 12.5 kHz.

Tympanometry and Stapedial Reflex Threshold

GSI Grason Stadler TympStar Pro is used in the department for tympanometry and SRT measurements. All participants in this study had middle ear pressures between +50 and -200 daPa. Ipsilateral stapedial reflexes were assessed using a 226 Hz probe tone, starting at 60 dB HL, and increasing in 5 dB steps until a minimal reflectance change of 0.02 ml was observed, which marked the threshold (21). The upper level of stimuli used to elicit the reflexes varied between 100- and 105-

dB HL. This is further explored in the data analysis section. Stapedial reflexes at frequencies of 1 kHz and 4 kHz were measured for both ears.

Uncomfortable Loudness Level (ULL)

Audiometer used for pure tone thresholds was also used to measure ULLs for both ears. Pure-tones were presented for one second, with at least a one-second interval between each stimulus, starting at 60 dB HL and increasing in 5 dB steps until the ULL was reached (20). The children were instructed to give a 'thumbs up' if they were comfortable with the stimuli and give a 'thumbs down' if a stimulus was uncomfortable. If ULL was not reached by 100 dB HL the measurement stopped for that frequency and the ULL was recorded as 105 dB HL. Such an approach is similar to Aazh and colleagues (2022) (12). The British Society of Audiology suggests limiting ULL measurement to minimum number of frequencies required for clinical purpose (20). The departmental protocol measured ULL for 1 and 4 kHz frequencies, to match up with the frequencies used for SRT, which helped the clinicians to explain the nature of DST to establish the patients understanding of the condition which in turn assisted in the counselling process involved in the management (further explained in discussion section).

Data Analysis

Statistical analyses were performed using SPSS version 29. The data were explored and were not normally distributed. Non-parametric tests were carried out. Bonferroni correction for multiple comparisons were applied for independent samples test to compare variables across the three group, if applicable. Categorical data were analysed using cross-tabulations and Chi-square tests. p-values < .05 were considered to be statistically significant. If p values are <.05 the actual significance levels are provided for appreciating the level of significance.

There are studies that replaced missing values with one audiometric step above the highest presentation level if no stapedial reflex was observed (34) or ULL not reached (12). Stapedial reflex is absent in a small proportion of healthy individuals (34,35), and the above approach may not be appropriate (34). Normally, SRT varies between 70 -100 dB HL in 95%, and between 65-105 dB HL in 99% of the population (35). It was therefore felt that the use of either 100 dB HL or 105 dB HL as the maximum levels of stimuli to record stapedial reflex would not significantly influence the outcome of the study. If stapedial reflexes were not recordable at 100- or 105-dB HL, they were recorded as 'no response' at 100- or 105-dB HL as appropriate. Unlike stapedial reflex that may be absent in about 5% of the population, ULL values were expected in all participants. In the study ULL measurements did not exceed 100 dB HL as such a level was clinically adequate for audiological evaluation and counselling. 105 dB HL was taken as ULL if ULL was not reached at 100 dB HL, consistent with some studies (12).

Results

Age, Gender, and NVIQ

Chi-square test demonstrated that 'Misophonia with hyperacusis' group had a significantly higher number of females compared to both the 'Hyperacusis only' group (p=.001) and the 'No DST' group (p=.002). Gender difference between the 'Hyperacusis only' and 'No DST' groups was not significant (p>.05).

Kruskal Wallis test suggested significant age differences between the three groups (p =.008). Pairwise comparisons with Bonferroni correction showed that the participants in the 'Misophonia with hyperacusis' group were significantly older than those in the 'Hyperacusis only' group (p=.007) without any age differences between the 'Misophonia with hyperacusis' versus the 'No DST' groups (p>.05) or the 'Hyperacusis only' versus the 'No DST' groups (p>.05). There were no significant differences in NVIQ among the three groups (p > .05).

Impact of DST on daily activities

There were two missing data from the 'Hyperacusis only' group. DST had 'significant impact' on daily activities in 25 out of 35 participants (71.4%) and in 62 out of 105 participants (59%) in the 'Misophonia with hyperacusis' and the Hyperacusis only' groups respectively, which was not statistically significant (Chi-square test, p>.05). In the 'Misophonia with hyperacusis' group, DST had 'significant impact' in 17 females and eight males, and 'non-significant impact' in seven females and three males, and this gender difference was not statistically significant (Chi-square test, p>.05). In the 'Hyperacusis only' group DST had 'significant impact' in 28 out of 39 females (71.8%) and in 34 out of 66 males (51.5%), which was statistically significant (Chi-square test, p <.05).

Hearing Thresholds

The mean (SD) pure-tone thresholds for the right and left ears at 0.25, 0.5, 1, 2, 4, 8, 10 and 12.5 kHz along with the means (SD) of .25 to 4 kHz (Low PTAvg) and 8 to 12.5 kHz (High PTAvg) pure-tone averages and the differences between the high and low frequency pure tone averages (High-Low PTAvg slope) are provided in Table 1. The hearing thresholds at each of the individual frequencies, High PTAvg and Low PTAvg were not significantly different across the three groups in either the right or the left ear (Kruskal Wallis test, p>.05). Wilcoxon signed-rank test suggested that High PTAvg were significantly lower than Low PTAvg within each of the three groups, for both the ears (p <.001). When compared across the groups, the High-Low PTAvg slope was found to be significantly different in the right ear (Kruskal Wallis test, p = .034). Pair-wise comparison with Bonferroni correction for multiple comparisons found that the High PTAvg in the right ear was significantly lower than the Low PTAvg in the 'misophonia with hyperacusis' group compared to the no 'DST' groups (p=.029).

Table 1. Here Please

Stapedial Reflex Threshold (SRT)

Different outcomes of ipsilateral stapedial reflex measurements are shown in Table 2. For 1 kHz tone, stapedial reflex was present in 178 out of 189 ears tested (94.17%) in the 'hyperacusis only' group, in 251 out of 261 ears tested (96.16%) in the 'no DST' group and in 61 out of 65 ears tested (93.84%) in the 'misophonia with hyperacusis' group. For 4 kHz tone, stapedial reflex was present in 140 out of 175 ears tested (80%) in the 'hyperacusis only' group, in 192 out of 255 ears tested (75.29%) in the 'no DST' group and in 49 out of 64 ears tested (76.56%) in the 'misophonia with hyperacusis' group. The mean and standard deviation of stapedial reflex thresholds at 1 and 4 kHz and the mean of the difference in thresholds between 4 kHz and 1 kHz (SRT 4-1 kHz slope) are shown in Table 3. There were no statistically significant differences in these measures of stapedial reflexes across the three groups, for neither the right nor the left ear (Kruskal Wallis test, p>.05).

Table 2. Here please

Table 3. Here please

Uncomfortable Loudness Level (ULL)

The number and percentage of participants with different ULLs varying from 60 to greater than 100 dB HL in the right and left ears for 1 and 4 kHz tones are provided in Table 4. High proportion of participants in all the groups had ULLs of 90 dB HL or greater. The mean and standard deviation of ULLs in response to 1 and 4 kHz tones and the difference in ULLs between 4 and 1 kHz (ULL 4-1 kHz slope) are shown in Table 3. Kruskal Wallis test suggested significant differences in ULLs across the three groups in both the right and left ears for both 1kHz and 4 kHz tones. Pairwise comparisons with Bonferroni correction showed no statistically significant differences in the above measures between the 'Hyperacusis only' and the 'Misophonia with hyperacusis' groups (p>.05). ULL was significantly higher in the 'No DST' group than the 'Hyperacusis only' group (Right 1 kHz, p=.003; Right 4 kHz, p<.001; Left 1 kHz, p=.008; Left 4 kHz, p =.001) as well as the 'Misophonia with hyperacusis' group (Right 1 kHz, p=.003; Right 4 kHz, p<.001; Left 1 kHz, p<.024; Left 4 kHz, p =.001). The ULL 4-1 kHz slope in the 'Misophonia with hyperacusis' group was lower compared to the 'No DST' group which reached statistical significance in the left ear (p=.035) but narrowly failed to reach statistical significance in the right ear (p=.052).

The ULLs in response to the 1 and 4 kHz tones in either the right or the left ears were not significantly different whether DST (Hyperacusis only or Misophonia with hyperacusis) were associated with either 'significant impact' or 'non-significant impact' on daily life (Mann-Whitney U tests, p>.05).

Table 4 Here please

Tinnitus

There were two and four missing data about the presence or absence of tinnitus in 'Hyperacusis only' and the 'No DST' groups respectively. Tinnitus was present in 32 (30.48%), 16 (45.71%) and 24 (18.18%) participants in the 'Hyperacusis only', 'Misophonia with hyperacusis' and the 'No DST' groups respectively. From the available data on the 'No DST' group, 50 participants never had DST and 82 participants had occasional DST. Of the 50 participants who never had DST, six (12%) complained of tinnitus, compared to tinnitus in 18 (21.9%) out of 82 participants who had very occasional DST. The number of participants with and without tinnitus in those who never complained of DST and those who had occasional DST was not statistically significant (Chi-square test, p>.05). The means (SD) of the age in years, NVIQ, and different audiological measures in participants with and without tinnitus in the three groups are provided in Table 5. Mann-Whitney U test compared the above variables between participants with and without tinnitus, in all the three groups separately. Participants with tinnitus were older in the 'Hyperacusis only' (p=.007) and the 'No DST' (p =.003) groups compared to those without tinnitus. No age difference was noted in the 'Misophonia with hyperacusis' group in terms of the presence or absence of tinnitus (p >.05). The presence or absence of tinnitus did not influence any of the audiological characteristics in the 'Hyperacusis only' and the 'Misophonia with hyperacusis' groups (p>.05). The right ear of participants with tinnitus in the 'No DST' group had highly significant lower ULL at 4 kHz (p=.003) with larger ULL slope between 4 and 1 kHz (p=.001) compared to those without tinnitus.

History of otitis media with effusion (Glue ear)

Data were missing in three and one participants about past history of otitis media with effusion from the 'Hyperacusis only' and the 'no DST' groups respectively. Twelve (11.54%), five (14.29%), and 16 (11.85%) participants in the 'Hyperacusis only', 'Misophonia with hyperacusis' and 'No DST' groups respectively had past history of otitis media with effusion. The proportion of participants with past history of glue ear were not statistically significantly different between the three groups (p > .05).

Discussion

Distinguishing between hyperacusis and misophonia is an increasingly significant topic in audiology (2,4,6,7). An association between increased sensitivity to high frequency sounds has been suggested in DST (12) but it is not clear how children with hyperacusis, misophonia and those without DST differ in respect of the pure-tone thresholds for low and high frequency tones. The use of stapedial reflex threshold and uncomfortable loudness levels in these groups of children are also not widely reported (25), especially in children with normal hearing thresholds. Most studies on DST concentrated on adults with different levels of hearing and tinnitus (11,12,36) and it is not clear how hearing loss and tinnitus influenced the findings. Some studies have looked into tinnitus and DST in children, but their relationship is not clear (25,37), especially in children with normal hearing thresholds. This current study investigated if hyperacusis and misophonia could be differentiated by characteristic audiological feature(s), by the presence and absence of tinnitus, and by past history of glue ear in children diagnosed with APD who have satisfactory hearing thresholds.

Prevalence of DST in children with APD

The reported prevalence of DST in children vary from 5.4 to 46% of the general paediatric population to 95% of children with Williams syndrome, dependent on how DST has been defined, the population being studied (25), and cultural environment (38). Ahmmed and Mukherjee (2021) reported that approximately 70% children with APD have DST, a study where children with occasional symptoms of oversensitivity to sounds were also considered to have DST (28). In the current study approximately 51% of children with APD had DST, where oversensitivity to sounds were present most times or always. Such prevalence of DST in APD is consistent with the reported prevalence of sensory oversensitivity in neurodevelopmental disorders (39). DST and APD can be seen in the context of a sensory processing disorder (28). APD coexists with different neurodevelopmental conditions that are associated with DST (12,40). The coexistence of different mental and neurodevelopmental conditions is clarified by the way different neural systems in the brain interacts as laid down in the Research Domain Criteria (RDoC) framework (41), which influenced not only APD to be evaluated within the RDoC framework (29) but also led to the proposal of application of RDoC framework in evaluating DST (6). The strong link between sensory processing and different neurodevelopmental condition has also influenced a proposal to include sensory processing as a separate system within RDoC (42).

Thirty-five out of the 278 participants (12.6%) in the current study had misophonia, consistent with the reported prevalence of misophonia that vary from 6-19% (12). The findings in this study of 24.6% participants with DST to have misophonia (35 misophonia out of 142 participants with DST) is also consistent with the 23% prevalence of misophonia reported by Aazh and colleagues (2022) in patients presenting with tinnitus and/or hyperacusis (12). In view of the high prevalence of DST in children with APD noted in this study and their associated co-morbidities it is important that DST and other neurodevelopmental conditions are considered in the APD diagnostic process, aligning with the RDoC framework (6,29,41). The current study highlights that the auditory disability in APD is not only limited to poor listening but also include DST and tinnitus.

The existing literature on hyperacusis and misophonia are mainly limited to the different triggers, different emotional responses, influence of DST on daily life, and some associated mental health conditions like anxiety, depression and obsessive-compulsive disorders (30). Limited amount of literature exists on the association between DST and general health and cross-cultural variation (32,38). However, a number of symptoms and conditions that may arise from the different systems represented within the RDoC framework have not been explored in a holistic way in evaluating DST.

The presence of too many different diagnostic approaches in DST can be confusing and there is a need of prospective studies to develop a validated approach in evaluating DST in a holistic way, exploring all the different RDoC systems (6).

Gender and DST

The relationship between gender and DST found in this study is consistent with the literature, for example the higher prevalence of misophonia in females (5,9,43,44) and that the impact of misophonia on life being similar in both females and males (45). The literature emphasizes that the diagnosis of DST and its impact on life are separate issues (30). Further studies are required to establish if the higher prevalence of misophonia in females is related to the higher prevalence of certain mental health conditions in females (46). In contrast to misophonia, the higher prevalence of hyperacusis alone in males in our study (61.7%) is also consistent with the 60.2% prevalence of hyperacusis in males reported by Hall and colleagues (24). Our study adds by suggesting that despite higher prevalence of hyperacusis in males the frequency of significant impact of hyperacusis were lower in males compared to females.

Prevalence of tinnitus in children with APD

The prevalence of tinnitus in children reported in this study (18.18 % in those without decreased sound tolerance, 30.48% in hyperacusis only, and 45.71% in misophonia with hyperacusis) is within the range mentioned in a systematic review of the literature of tinnitus and hyperacusis in children (37). Hall and colleagues (2016) reported a 42% prevalence of tinnitus in hyperacusis in 260 children aged 11 years (24). The high prevalence of tinnitus in misophonia in children as shown in the current study is also consistent with the adult literature (4,12). Additionally, our study in children supports the notion that prevalence of tinnitus increases with age, and in an adult population with hyperacusis prevalence of tinnitus has been reported to increase to around 86% (19).

DST and pure-tone audiometric measures

DST has been suggested to be related to increased sensitivity to high frequency tones. Aazh and colleagues reported that hearing thresholds at 8kHz were lower than that at 1 kHz, in predominantly adults with more severe misophonia symptoms compared to those with lesser symptoms (12,22). The current study could not be directly compared with the above study but demonstrated that the High PTAvg was lower than the Low PTAvg irrespective of the presence or absence of DST. The present study adds to the literature by demonstrating that misophonia is associated with lower High PTAvg compared to Low PTAvg in the right ear compared to those without DST. The ear asymmetry is further discussed later in the ULL and tinnitus sections.

Stapedial Reflex

The higher proportion of no response or absent stapedial reflexes in response to 4 kHz tones (20%, 24.7% and 23.4% in the 'Hyperacusis only', 'no DST' and 'Misophonia with hyperacusis' groups respectively) compared to 1 kHz tone (5.8%, 3.8% and 6.1% in the 'Hyperacusis only', 'no DST' and 'Misophonia with hyperacusis' groups respectively) in the current study (table 2) is consistent with the literature (34,35). The mean SRTs reported in the current study (Table 3) are very similar to the 85 dB HL reported by Anari and colleagues (1999) in their study of 44 females (age range 22-76 years) and 56 males (age range 9-67 years) with hyperacusis (19). The above study also corroborates the results of the current study, indicating that SRTs in response to different frequency tones do not vary significantly. Saxena et al. (2020) reported that SRT could be elicited by broadband stimuli using intensity about 20 dB HL lower than that of pure-tone stimuli (17). Future research studies would be useful to explore if broadband stimuli would be more appropriate for stapedial reflex measurement in individuals with DST.

ULL (Uncomfortable Loudness Level)

Siepsiak and colleagues (2022) measured ULLs at 0.125, .5, 1, 2, 4 and 8 kHz tones in adults and reported mean ULLs of 84.4, 85.4, and 89.96 dB HL for misophonia, hyperacusis and a control group respectively for the right ear, and 86.5, 85, and 89.99 dB HL respectively for the left ear (44). The above study reported no significant differences between the three groups in contrast to the current study of lower ULLs in hyperacusis with or without misophonia compared to no DST. The present study is consistent with Aazh and colleagues reporting lower ULLs for high frequency tones compared to low frequency tones in misophonia (12) and hyperacusis (22). However, unlike the current study, Aazh and colleagues (12,22) measured ULLs for a large number of tones including 8 kHz in evaluating patients with tinnitus and/or hyperacusis. The study by Aazh and colleagues compared one group with high misophonia scores with another group with low misophonia score (12), but unlike the current study did not include a true control group without DST. The above study did not find any ear asymmetry for ULL. In the current study ULLs for 4 kHz in the right ear were lower at a highly significant levels ($p<.001$) in both the groups with DST ('Misophonia with hyperacusis' and 'Hyperacusis only') compared to the 'No DST' group after adjusting for multiple comparisons. In contrast 1 kHz ULLs in the left ear were significant at a lesser degree ($p=.003$) in both the DST groups compared to the 'No DST' group. The above findings along with significant lower pure-tone average for high frequency sounds in the right ear in the misophonia group suggest some asymmetry between the ears, and the right ear dominance may play a role. At this point it needs to be noted that although the ULL 4-1kHz slope was weakly significant between misophonia and no DST groups in the left ear ($p=.035$) and it almost reached significant level ($p=.052$) in the right ear. The number of participants with misophonia in the current study was small and future studies with larger misophonia participants would be helpful to clarify the ear asymmetry.

The wide variation in ULL values reported in the literature and the findings in this study support the view that ULL have poor sensitivity and specificity (14) and is questionable as a diagnostic marker of DST (1,13). The current study adds to the literature by suggesting that ULLs did not correlate with the impact DST on daily life.

Discrepancy between SRT and ULL and their clinical value

In contrast to ULL, stapedial reflex is seen as an objective measure of the integrity of the auditory pathway and its sensitivity to sound (15,17,47). The findings of similar values of SRTs in those with and without DST in the current study despite low ULLs in those with DST (table 3) is consistent with the literature that there are no correlations between ULL and SRT (15). This raises the question if SRT measurement can complement ULL in the clinical evaluation of DST. In the absence of any solid link between auditory tests and DST, the value of subjecting individuals with DST to loud sounds to obtain SRT and ULL may be questioned.

The absence of any difference in the SRTs in the three groups and low ULL in DST in the current study would suggest that ULL is mediated by higher order brain networks compared to the brain stem involved in stapedial reflex. Both hyperacusis and misophonia are linked to activation of the limbic system (11) and associated with anxiety, mental health issues and neurodevelopmental disorder (3,10,28). Different forms of Cognitive Behavioural Therapy such as positive affect labelling, emotional reappraisal, acceptance amongst others helps in the management of DST (48,49). For such approach to work it is important to convince individuals about the normal integrity of the ears and the auditory pathway, and that DST arise from negative interpretation of the sounds by the brain and influenced by different factors (4,17,18,20). In the APD clinics run by the corresponding author children are preconditioned by explaining the nature of DST prior to SRT and ULL measurements. In individuals with normal pure-tone audiogram, the presence of stapedial reflex helps in reassuring that the auditory pathway is intact, and the protective auditory reflex is responding normally to loud sounds. This in turn helps in the acceptance of ULL measurement with less variable results. In the longer term the audiological assessments help with the counselling, management, and monitoring progress.

Tinnitus and other audiological findings in DST

Tinnitus in 48 (32 plus 16) out of 140 participants with DST (hyperacusis only, 105 plus misophonia with hyperacusis, 35) in the current study, suggests a prevalence of tinnitus in children with DST in APD of 34%. This is lower than the 86% prevalence of tinnitus reported in adults with hyperacusis (19) but is similar to the 27.7% prevalence of tinnitus in a collegiate population with likelihood of hyperacusis and/or misophonia (50). The latter study is consistent with our current study demonstrating a significant association between tinnitus and misophonia (50). The current study adds to the literature by demonstrating that low ULLs are not only associated with DST but also with tinnitus in children without DST (Table 5). Further research is needed to establish if these children with tinnitus without DST develops DST later on life, or in other words if the tinnitus is a precursor of DST. The significantly lower ULL for 4 kHz compared 1 kHz tone in the right ear in the 'No DST' group with tinnitus and the relatively lower High PTAvg compared to Low PTAvg in the right ear in misophonia may be linked to right ear dominance (51). In view of the findings, it would be important to enquire about DST in children presenting with tinnitus.

OME and DST

Some of the participants of this study had a past history of otitis media with effusion (OME, glue ear), years before their APD was diagnosed after resolution of OME with restoration of the hearing thresholds to normal. Some studies suggest an association between OME and DST in young children (26). Eight out of 10 children in the general population will develop OME at some point that resolves spontaneously (23), therefore it is not surprising that many young children presenting with DST will naturally have glue-ear. However, to establish an association between glue ear and DST there is a need of a control group. The current study demonstrates that the prevalence of past history of OME was similar in children with or without DST. The lack of any difference in the prevalence of past history of OME in those with and without DST supports the view that temporary conductive loss may increase the auditory gain for a short time, and it settles once the conductive hearing loss is restored (52). The present study rules out past history of OME or glue-ear as a cause of DST.

Limitations

A number of issues limit the generalizability of the findings in this study that was carried out in children diagnosed with APD. Consistent with the literature misophonia mostly co-existed with hyperacusis that makes it difficult to conclude if the lack of difference in the audiological characteristics found in this study was due to this overlap. Future research is needed to compare between 'misophonia without hyperacusis' and 'hyperacusis without misophonia'. This would involve a long-term study as the prevalence of 'misophonia without hyperacusis' is very small (3,4,11). The relatively smaller number of children in the 'misophonia with hyperacusis' group compared to the 'hyperacusis only' group is also an issue. There are ambiguities in the definitions of misophonia and hyperacusis in the current literature and future research is required to establish a clearer and standardized definitions based on clinical presentation and neurophysiological basis (4). The incorporation of all the systems within the RDoC framework may be a way to standardize the evaluation of DST in a holistic way and reaching a consensus (6). In the current paper misophonia referred to DST to sounds of chewing and eating as this is the predominant trigger (9) and the term 'mastication rage' has been used (8) to refer to misophonia. Future research is needed to establish if audiological, behavioural and emotional responses of children with DST to other body sounds such as breathing, coughing, sneezing and others differ from those with hyperacusis and DST to chewing and eating.

Conclusion

The current study primarily aimed to explore if 'hyperacusis' and 'misophonia' could be distinguished using routine audiological assessment. Thresholds of individual pure-tones used in pure-tone audiometry were not different between those with or without DST in children with APD with thresholds considered to be within normal limits of 20 dB HL. However, 'misophonia with hyperacusis' group had lower pure-tone average of high frequency (8, 10, 12.5 kHz) tones compared to pure-tone average of low frequency (.25, .5, 1, 2 and 4 kHz) tones in the right ear compared to the 'No DST' group. Ipsilateral SRTs were similar irrespective of DST. ULLs were lower in both 'misophonia with hyperacusis' and 'hyperacusis only' groups compared to those without DST. However, ULLs did not vary significantly weather the DST had significant or non-significant impact on daily life. In the 'No DST' group those with tinnitus had lower ULL for 4 kHz compared to 1 kHz tone in the right ear compared to those without tinnitus. There were some inconsistencies regarding the ear asymmetry for ULL and future studies are required with larger sample of misophonia. The study findings are consistent with the literature that stapedial reflex involves the inner ears and the brain stem (17) , while hyperacusis, misophonia and tinnitus involves higher order brain networks mediating emotional responses and anxiety (11). The study is consistent with the literature that there is no direct link between audiological findings and DST (18). However, audiological assessment in DST is considered useful for clinical evaluation, counselling and management.

Tinnitus was more common in 'misophonia with hyperacusis' group compared to 'hyperacusis only' and 'No DST' groups, and in the 'hyperacusis only' group compared to the 'No DST' group. Children with misophonia with or without tinnitus and children with tinnitus in the 'hyperacusis only' and the 'No DST' groups were older. The study findings are consistent with the literature that stapedial reflex involves the inner ears and the brain stem (17) , while hyperacusis, misophonia and tinnitus involves higher order brain networks mediating emotional responses and anxiety (11). We suggest that DST and tinnitus are considered as auditory disabilities in addition to different types of listening difficulties in evaluating APD, and DST needs to be explored in children presenting with tinnitus.

Misophonia was more prevalent in females but the frequency of significant impact of misophonia on daily life were similar in both females and males. In contrast to misophonia, hyperacusis was more prevalent in males but significant impact of hyperacusis on daily living was more frequent in females.

The association between DST and past history of OME was also explored in this study. Similar prevalence of past history of glue-ear in APD children with or without DST suggests that OME is unlikely to be a factor leading to DST in older children and adolescents.

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Table 1. Mean (SD) of pure tone thresholds (HT) at 0.25 kHz to 12.5 kHz and pure tone averages for 0.25 kHz-4 kHz and 8kHz-12.5 kHz.

		0.25 kHz	0.5 kHz	1 kHz	2 kHz	4 kHz	8 kHz	10 kHz	12.5 kHz	Average .25-4kHz	Average 8-12.5 kHz	High-low slope
HT Right	Hyperacusis only	9.15 *(5.91)*	12.01 *(5.53)*	8.93 *(5.23)*	6.31 *(5.15)*	6.54 *(6.77)*	5.75 *(7.26)*	5.52 *(7.9)*	4.42 *(8.59)*	8.59 *(4.40)*	**5.27**** *(6.90)*	-3.32 *(5.36)*
	Misophonia with Hyperacusis	11.43 *(5.76)*	13 *(5.17)*	9 *(5.39)*	7.57 *(5.19)*	7 *(5.02)*	4.29 *(6.76)*	5.57 *(6.27)*	4.0 *(7.65)*	9.57 *(4.21)*	**4.61**** *(5.91)*	**-4.98*** *(4.59)*
	No Decreased sound tolerance	8.77 *(5.73)*	12.46 *(4.98)*	7.72 *(4.70)*	5.85 *(5.14)*	5.88 *(5.89)*	5.63 *(6.56)*	5.60 *(6.77)*	4.18 *(7.23)*	8.13 *(3.76)*	**5.16**** *(5.62)*	-2.97 (4.89)
HT Left	Hyperacusis only	9.72 *(5.68)*	11.92 *(4.69)*	7.85 *(5.28)*	6.36 *(5.97)*	7.99 *(6.25)*	5.98 *(7.60)*	5.94 *(8.08)*	6.52 *(8.85)*	8.77 *(4.28)*	**6.23**** *(7.15)*	-2.53 *(5.66)*
	Misophonia with Hyperacusis	10.57 *(6.39)*	13.14 *(5.43)*	8 *(5.96)*	6.71 *(6.52)*	8.71 *(4.75)*	4.57 *(6.79)*	5.43 *(6.10)*	4.86 *(8.17)*	9.42 *(4.54)*	**4.95**** *(5.56)*	-4.47 *(4.99)*
	No Decreased sound tolerance	9.46 *(6.03)*	12.66 *(5.40)*	7.61 *(5.54)*	5.82 *(4.94)*	8.13 *(6.49)*	5.70 *(6.55)*	5.86 *(8)*	5.45 *(8.86)*	8.73 *(4.26)*	**5.66**** *(6.56)*	-3.11 *(5.79)*

**High frequency pure-tone averages significantly higher than low frequency average in all the groups, p<001
* High and low frequency pure-tone average difference significantly lower in the Misophonia group compared to No DST group, p<.05

Table 2. Outcome of ipsilateral stapedial reflexes at 1 and 4 kHz tones in the right and left ears in the hyperacusis only, no DST and misophonia with hyperacusis groups.

		Number of participants			
		1 kHz		4 kHz	
	Stapedial reflex response types	**Right Ear**	**Left Ear**	**Right Ear**	**Left Ear**
Hyperacusis only (n=107)	Present	92	86	73	67
	No response at 100-105 dB HL	6	5	15	20
	Not tested	0	1	2	2
	Missing	9	15	17	18
No DST (n=136)	Present	129	122	94	98
	No response at 100-105 dB HL	3	7	33	30
	Not tested	1	1	2	1
	Missing	3	6	7	7
Misophonia with hyperacusis (n=35)	Present	29	32	23	26
	No response at 100-105 dB HL	3	1	9	6
	Not tested	1	1	2	2
	Missing	2	1	1	1

Table 3. Mean (SD) of ipsilateral stapedial reflex thresholds and uncomfortable loudness levels elicited using 1 and 4 kHz tones and their slopes (difference between responses at 4 and 1 kHz tones) in the right and left ears.

	1 kHz				*4 kHz*				Differences between *4 & 1 kHz*			
	SRT Rt	ULL Rt	SRT Lt	ULL Lt	SRT Rt	ULL Rt	SRT Lt	ULL Lt	SRT 4-1 Rt	ULL 4-1 Rt	SRT 4-1 Lt	ULL 4-1 Lt
Hyperacusis only	90.11 *(10.24)*	**93.30**** *(10.53)*	88.55 *(10.84)*	**92.31**** *(11.46)*	89.04 *(9.84)*	**91.42***** *(11.68)*	86.12 *(10.25)*	**92.45***** *(11.65)*	.07 *(9.33)*	-1.93 *(5.19)*	-2.39 *(9.58)*	.14 *(5.58.)*
Misophonia with hyperacusis	87.41 *(11.62)*	**91.57**** *(10.69)*	89.53 *(10.57)*	**91.43*** *(11.21)*	83.48 *(13.52)*	**88.29***** *(11.17)*	87.31 *(10.79)*	**90.29***** *(11.62)*	-1.9 *(7.49)*	-3.14 *(5.56)*	-.77 *(9.86)*	**-1.29*** *(4.43)*
No Decreased sound tolerance	89.53 *(10.57)*	97.86 *(8.3)*	88.85 *(9.87)*	96.84 *(8.51)*	86.94 *(10.37)*	97.26 *(8.67)*	87.04 *(10.12)*	97.97 *(8.23)*	-.59 *(11.07)*	-.64 *(5.12)*	-.15 *(9.44)*	.94 *(4.44)*

****Right and Left ears 4 kHz; ULL higher in 'no DST' group compared to 'misophonia with hyperacusis' and 'hyperacusis' group (p<.001)*

*** ULL higher in 'no DST' group compared to 'misophonia with hyperacusis' and 'hyperacusis' groups in right ear and hyperacusis group in Left ear for 1kHz tone (p<.01)*

**ULL higher in 'no DST' group compared to 'misophonia with hyperacusis' group in Left ear for 1kHz tone; Left ULL significantly lower at 4 than 1 kHz in 'misophonia with hyperacusis' group compared to 'no DST' group (p<.05)*

Table 4. Number (percentage) of ULL responses at different levels from 60 to >100 dB HL using 1 and 4 kHz tones in the three groups.

		60 dB HL	65 dB HL	70 dB HL	75 dB HL	80 dB HL	85 dB HL	90 dB HL	95 dB HL	100 dB HL	>100 dB HL
Hyperacusis Only	ULL Rt 1 kHz	0	0	3 (2.83)	7 (6.6)	10 (9.43)	13 (12.26)	13 (12.26)	14 (13.21)	15 (14.15)	31 (29.24)
	ULL Rt 4 kHz	0	3 (2.83)	4 (3.77)	8 (7.55)	11 (10.38)	15 (14.15)	11 (10.38)	13 (12.26)	13 (12.26)	28 (26.41)
	ULL Lt 1kHz	1 (.94)	1 (.94)	7 (6.6)	4 (3.77)	9 (8.49)	11 (10.38)	14 (13.21)	14 (13.21)	20 (18.86)	25 (23.58)
	ULL Lt 4 kHz	1 (.94)	2 (1.89)	3 (2.83)	8 (7.55)	10 (9.43)	10 (9.43)	13 (12.26)	12 (11.32)	19 (17.92)	28 (26.41)
Misophonia with Hyperacusis	ULL Rt 1 kHz	0	0	2 (5.71)	4 (11.43)	1 (2.86)	4 (11.43)	4 (11.43)	9 (25.71)	5 (14.28)	6 (17.14)
	ULL Rt 4 kHz	0	1 (2.86)	3 (8.57)	2 (5.71)	6 (17.14)	4 (11.43)	3 (8.57)	8 (22.85)	3 (8.57)	5 (14.28)
	ULL Lt 1 kHz	0	2 (5.71)	1 (2.86)	1 (2.86)	2 (5.71)	6 (17.14)	4 (11.43)	7 (20)	6 (17.14)	6 (17.14)
	ULL Lt 4 kHz	0	3 (8.57)	1 (2.86)	3 (8.57)	1 (2.86)	6 (17.14)	6 (17.14)	5 (14.28)	3 (8.57)	7 (20)
No Decreased Sound Tolerance	ULL Rt 1 kHz	0	0	1 (.75)	2 (1.5)	6 (4.51)	10 (7.52)	12 (9.02)	16 (12.03)	33 (24.81)	53 (39.84)
	ULL Rt 4 kHz	0	0	0	4 (3)	5 (3.76)	14 (10.53)	15 (11.28)	16 (12.03)	24 (18.04)	55 (41.35)
	ULL Lt 1 kHz	0	0	0	2 (1.5)	10 (7.52)	12 (9.02)	13 (9.77)	19 (14.28)	30 (22.55)	47 (35.33)
	ULL Lt 4 kHz	0	0	0	0	9 (6.77)	14 (10.53)	9 (6.77)	16 (12.03)	27 (20.3)	58 (43.61)

Table 5. Comparison of mean (SD) of age, non-verbal intelligence, and different audiological measures in participants with and without tinnitus in the three groups of children diagnosed with auditory processing disorder.

	Hyperacusis only		Misophonia with hyperacusis		No DST	
	Tinnitus Present	Tinnitus Absent	Tinnitus Present	Tinnitus Absent	Tinnitus Present	Tinnitus Absent
Age in years	**12.24 (*2.24*)****	**10.85 (*2.03*)**	12.58 *(2.54)*	12.53 *(2.38)*	**12.80 (*1.98*)****	**11.41 (2.05)**
NVIQ	98.75 (*8.25*)	99.99 *(10.87)*	101.25 *(13.48)*	93.42 *(5.53)*	97.54 *(10.88)*	98.97 *(9.35)*
PTavg 0.25-4kHz Right	8.68 *(4.92)*	8.47 *(4.2)*	10.75 *(4.89)*	8.63 *(3.32)*	8.03 *(4.24)*	8.13 *(3.7)*
PTavg 8-12.5kHz Right	6.26 *(7.54)*	4.84 *(6.6)*	6.14 *(5.15)*	3.33 *(6.33)*	4.85 *(5.5)*	5.06 *(5.61)*
Slope PTavg Hi-Lw Rt	-2.44 *(6.37)*	-3.63 *(4.87)*	-4.60 *(4.48)*	-5.29 *(4.77)*	-3.14 *(4.43)*	-3.07 *(4.98)*
PTavg 0.25-4kHz Left	9.12 *(4.93)*	8.59 *(4.01)*	10.87*(5.61)*	8.21 *(3.04)*	8.06 *(4.37)*	8.75 *(4.18)*
PTavg 8-12.5kHz Left	6.51 *(7.05)*	6.13 *(7.27)*	6.77 *(4.99)*	3.42 *(5.67)*	6.15 *(6.08)*	5.19 *(6.46)*
Slope PTavg Hi-Lw Lt	-2.61 *(6.16)*	-2.46 *(5.53)*	-4.10 *(4.99)*	-4.78*(5.10)*	-2.13 *(5.63)*	-3.56 *(5.77)*
SRT 1 kHz Right	91.6 *(10.87)*	89.7 *(10.03)*	88.00 *(13.33)*	86.79 *(9.92)*	91.52 *(9.1)*	89.36 *(10.66)*
SRT 1 kHz Left	90.65 *(11)*	87.78 *(10.76)*	90.31 *(12.31)*	88.75 *(8.85)*	89.77 *(8.51)*	88.44 *(10.21)*
SRT 4 kHz Right	88.64 *(10.59)*	89.3 *(9.69)*	82.73 *(14.89)*	84.17 *(12.76)*	87.08 *(7.52)*	86.79 *(10.84)*
SRT 4 kHz Left	85.71 *(11.21)*	86.3 *(9.91)*	86 *(12.08)*	88.21 *(9.92)*	89.64 *(6.34)*	86.65 *(11.02)*
SRT dif 4-1 kHz Right	-2.38*(8.74)*	.98 *(9.54)*	-1.50 *(4.73)*	-2.27 *(9.58)*	-.83 *(4.68)*	-1.03 *(11.66)*
SRT dif 4-1 kHz Left	-5.24 *(10.54)*	-1.09*(8.93)*	-2.08 *(13.39)*	.36 *(5.70)*	2.33 *(9.79)*	-.54 *(9.28)*
ULL 1 kHz Right	91.13 *(10.22)*	94.38 *(10.67)*	90.94 *(11.28)*	92.11 *(10.45)*	95.91 *(8.25)*	98.32 *(8.32)*
ULL 1 kHz Left	90.00 *(11.76)*	93.77*(10.98)*	90.31 *(12.17)*	92.37*(10.58)*	***92.5 (9.09)****	*97.71 (8.19)*
ULL 4 kHz Right	89.52 *(12.06)*	92.6 *(11.39)*	85.94 *(11.57)*	90.26 *(10.73)*	**92.05 (*9.46*)****	**98.46 (*8.19*)**
ULL 4 kHz Left	90.65 *(11.45)*	93.70 *(11.48)*	89.06 *(12.41)*	91.32 *(11.16)*	**93.86 (*9.12*)***	98.88 *(7.84)*
ULL dif 4-1 kHz Right	-1.77*(5.25)*	-1.78 *(5.09)*	-5.00 *(6.83)*	-1.58 *(3.74)*	**-4.09 (*6.29*)****	**.14 (*4.57*)**
ULL dif 4-1 kHz Left	.65 *(5.43)*	-.07 *(5.68)*	-1.25 *(3.41)*	-1.32 *(5.22)*	1.36 *(4.41)*	.93 *(4.51)*

*** Participants with tinnitus were significantly older than those without tinnitus in the 'Hyperacusis only' (p=.007) and the 'No DST' (p=.003) groups. In the 'No DST' group children with tinnitus had highly significant low ULL for 4 kHz tone (p=.003) with highly significant larger difference between the 4 and 1 kHz tones (p=.001) in the right ear.*

**Participants in the 'No DST' group children with tinnitus had mildly significant low ULL values for 1kHz (p=.013) and 4 kHz (p=.015) tones in the left ear compared to those without tinnitus.*

Title: A Retrospective Study of Audiological Characteristics of Hyperacusis versus Misophonia in Children with Auditory Processing Disorder

Highlights:

- Hyperacusis, misophonia and tinnitus are auditory disabilities in addition to the main symptom of listening difficulty in developmental auditory processing disorder.
- Routine audiological measures can not distinguish between hyperacusis and misophonia.
- Misiphonia is more common in females but the severity of impact on life are similar in both males and females.
- Hyperacusis more common in males but the frequency of significant impact of hyperacusis on life is higher in females.
- Stapedial reflex thresholds are similar in those with and without decreased sound tolerance (DST).
- Uncomfortable loudness levels (ULLs) are low in DST but ULLs do not reflect the frequency of significant impact of DST on life.
- In children without DST, ULLs are lower in those with tinnitus compared to those without tinnitus.
- DST is not related to history of otitis media with effusion in early childhood.

Declaration of interests

We have nothing to declare.