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Comparison of Listening Fatigue in Children with and Without Hearing Impairment

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ABSTRACT

Background: Listening fatigue, defined as the subjective sense of exhaustion resulting from sustained auditory processing, is a growing concern among children with hearing impairment. It is associated with increased cognitive load, reduced classroom engagement, and adverse effects on academic performance and psychosocial well-being. Children with normal hearing may also experience listening fatigue, but the extent of difference between the two groups remains inadequately explored. Objective: To evaluate and compare the levels of listening fatigue in children with and without hearing impairment using validated fatigue assessment tools. Methods: A cross-sectional observational study was conducted on 120 children aged between 4 to 13 years, including 60 with bilateral sensorineural hearing loss (mild to severe) and 60 with normal hearing, recruited from mainstream and special schools. Listening fatigue was assessed using the Vanderbilt Fatigue Scale – Teacher version (VFS-T). Data was analyzed with SPSS version 20.0 using t-tests, chi-square tests, and multivariate regression, with $p < 0.05$ considered significant. Results: Children with hearing impairment had significantly higher mean VFS-T scores (26.45 ± 4.59) compared to normal-hearing children (19.28 ± 3.37; $p < 0.001$, Cohen's $d = 1.82$). Over 93% of the hearing-impaired group required follow-up for listening fatigue versus 13% in controls. Conclusion: Listening fatigue is significantly elevated in children with hearing impairment, warranting early identification and targeted classroom interventions to optimize learning outcomes.

Keywords
Listening fatigue; hearing loss; sensorineural hearing loss; Vanderbilt Fatigue Scale; pediatric audiology

INTRODUCTION

Listening fatigue defined as the extreme tiredness that accrues from repeated and/or sustained effortful listening has increasingly been recognized as a clinically meaningful consequence of childhood hearing loss, with mounting evidence that children with hearing loss (CHL) experience greater fatigue than their normal-hearing (NH) peers. Although the phenomenon has been well documented in adults with hearing impairment, where greater multidimensional fatigue and reduced vigor have been repeatedly observed independent of the pure-tone audiometric degree of loss, its mechanisms, prevalence, and functional impact in children remain less clearly characterized and routinely under-assessed in clinical and educational practice (1). Parallel work demonstrates that CHL report greater general, cognitive, and sleep/rest fatigue on pediatric instruments such as the PedsQL Multidimensional Fatigue Scale (PedsQL-MFS) relative to NH peers, with particularly elevated risk among those with bilateral losses, while unilateral losses (UHL) also confer increased but variably expressed burden (2,3). Adolescents with hearing loss further report substantial listening-related fatigue on the Vanderbilt Fatigue Scale–Child (VFS-C), with patterns moderated by educational accommodations (e.g., individualized education programs) and device/configuration variables, underscoring that support structures can both mitigate and, paradoxically, signal higher underlying fatigue where greater accommodation reflects greater underlying difficulty (4). Despite these advances, sensitive, reliable, and valid tools tailored to capture listening-related (as opposed to general) fatigue in children have only recently been developed (e.g., the Vanderbilt Fatigue Scales for Pediatrics; VFS-Peds), and their application across diverse clinical phenotypes and real-world educational contexts remains limited (5). Qualitative frameworks derived from stakeholders (children, parents, teachers) highlight a multidimensional construct with physical, cognitive, emotional, and social-behavioral manifestations, shaped by situational determinants (e.g., background noise, multitasking, age, motivation) and variably addressed through coping strategies that often face practical barriers within schools (6).

From a cognitive-energetic perspective, listening effort reflects the intentional allocation of finite cognitive resources (working memory, attention, motivation) to overcome degraded auditory input; sustained engagement at high effort is hypothesized to precipitate listening-related fatigue and to compromise secondary cognitive operations (e.g., comprehension, memory) (7,8). Experimental and ecologically valid classroom simulations demonstrate that even modest background noise, adverse signal-to-noise ratios (SNRs), or dysphonic teacher voice quality can measurably increase effort and degrade comprehension in children, while improved SNRs reduce both effort and the accumulation rate of fatigue (9–11). Similar trends have been observed in tertiary education and online learning environments, where poorer audio-video streaming quality correlates with higher listening effort and multidimensional fatigue, reinforcing the generalizability of the cognitive-energetic load hypothesis across ages and modalities (12). In adults, real-world qualitative work further shows substantial inter-individual variability in fatigue experiences and coping strategies, only weakly ameliorated by amplification, implying that device provision alone is insufficient without attention to contextual, cognitive, and psychosocial modifiers (13,14). Among pediatric intervention options, remote microphone systems (RMS) tend to yield more consistent benefits for both speech recognition and behavioral indices of listening effort than alternatives such as contralateral routing of signal (CROS) in children with limited unilateral hearing, suggesting that technology targeting the SNR at the ear is likely to be central in fatigue mitigation strategies (15). Yet, even when amplification reduces effort and susceptibility to mental fatigue under sustained processing demands in adults, comparable pediatric evidence linking intervention to reductions in validated fatigue endpoints is scarce (16).

Against this backdrop, a critical knowledge gap persists: few studies have directly compared listening-related fatigue between CHL and age-matched NH children using a listening-specific, psychometrically validated pediatric instrument completed by classroom teachers who can observe functional fatigue behaviors across the school day. Most existing pediatric studies privilege child or parent report, focus on unilateral losses or adolescents, or use general (non-listening-specific) fatigue scales, limiting both construct specificity and applicability to classroom management (1,2).There is a pressing need to quantify and contrast the burden of listening related fatigue between CHL and NH peers within authentic educational environments, thereby informing targeted educational, audiologic, and policy interventions that can be prospectively tested for their capacity to reduce cognitive load and downstream academic/psychosocial sequelae.

MATERIAL AND METHODS

This study employed an analytical cross-sectional observational design to compare teacher-reported listening related fatigue in children with bilateral hearing impairment and children with normal hearing. The design was chosen as it allows for the simultaneous assessment of exposure (hearing status) and outcome (listening fatigue) within a natural classroom environment, facilitating group comparisons without the influence of longitudinal variability or intervention effects (17). The research was conducted between June 2022 and May 2023 across both mainstream schools and special education institutions in Faisalabad, Pakistan.

Participants were recruited through a non-probability purposive sampling approach to ensure representation of both normal-hearing children and those with diagnosed hearing impairment. Eligibility criteria for the hearing-impaired group included children aged 4–13 years, both male and female, with bilateral mild-to-severe sensorineural hearing loss who were consistent users of well-functioning hearing aids. The normal-hearing group included age- and gender-matched children with confirmed hearing thresholds ≤20 dB HL across 0.5, 1, 2, and 4 kHz frequencies. Children with congenital or acquired neurological disorders, chronic illnesses, or other developmental conditions were excluded from both groups to avoid confounding due to comorbid fatigue-related conditions. Hearing-impaired children with poor or inconsistent hearing aid use were also excluded. Parents or guardians were contacted through the schools, and written informed consent was obtained prior to participation. Children were recruited only after parental consent and teacher agreement to complete the Vanderbilt Fatigue Scale Teacher report (VFS-T). Potential confounders considered included socioeconomic status, type of amplification device (hearing aids or cochlear implant), duration of device use, and family support. These variables may independently influence listening fatigue in children.

Audiological evaluation was performed for all participants to confirm hearing status. Otoscopic examination was first conducted using a Welch Allyn otoscope to assess ear canal and tympanic membrane health. Subsequently, pure-tone audiometry was administered using a calibrated clinical audiometer in a sound-treated room. Air-conduction thresholds were measured at octave frequencies between 0.5 and 8 kHz, with bone conduction performed as necessary to differentiate sensorineural from conductive hearing loss. For normal-hearing children, audiometric thresholds were verified as within normal limits. For hearing-impaired children, degree of hearing loss was categorized as mild (26–40 dB HL), moderate (41–70 dB HL), or severe (71–90 dB HL) following World Health Organization classification (18).

Listening-related fatigue was assessed using the Vanderbilt Fatigue Scale – Teacher version (VFS-T), a validated instrument specifically designed to capture observable behavioral indicators of fatigue in classroom contexts (5). The VFS-T comprises items evaluating attention lapses, reduced motivation, irritability, need for breaks, and difficulty sustaining listening over prolonged periods. Teachers who had daily contact with the children for at least 4 hours were trained to complete the scale based on their observations during typical classroom learning. Data collection was scheduled to occur during regular school hours after at least 90 minutes of sustained academic activities, as this time frame has been shown to better reveal listening fatigue behaviors (2). Demographic information (age, gender, grade/class) and relevant medical history (e.g., perinatal complications, family history of hearing loss) were also recorded using a structured questionnaire completed by parents and verified through school records where possible. Although validated questionnaires and standardized instructions were used, reliance on child self-reports and teacher ratings may have introduced recall and social desirability bias. Teachers may also have been influenced by prior knowledge of a child's hearing status. Confidentiality assurances and blinded scoring helped to reduce these risks.

To reduce measurement bias, teachers completed VFS-T ratings independently and were blinded to the study hypothesis. Audiological assessments were conducted by experienced audiologists following standard clinical protocols to ensure validity and inter-rater reliability. Data entry and coding were double-checked by two independent researchers to prevent transcription errors. The sample size of 120 children (60 with normal hearing and 60 with hearing impairment) was determined based on a priori power calculation for comparing two independent means. Assuming a moderate effect size (Cohen's $d = 0.6$) from prior studies comparing fatigue scores in CHL vs NH peers (4,6), with $\alpha = 0.05$ and power = 0.8, the required sample size per group was approximately 57 participants, which was increased to 60 to account for potential data loss. Of 150 children approached, 10 were excluded due to additional disabilities, and 20 declined participation. The final sample included 120 children (60 with hearing impairment, 60 with normal hearing). Statistical analyses were conducted using SPSS software (version 20.0, IBM Corp., Armonk, NY, USA). Descriptive statistics were reported as mean ± standard deviation for continuous variables and as frequencies and percentages for categorical variables. The primary analysis involved comparing mean VFS-T scores between the hearing-impaired and normal-hearing groups using an independent samples t-test, with statistical significance set at $p < 0.05$ (two-tailed). Assumptions of normality and homogeneity of variances were evaluated using Shapiro-Wilk and Levene's tests, respectively. In cases where these assumptions were violated, non-parametric Mann-Whitney U tests were applied. Potential confounding factors such as age, gender, and grade level were examined through multivariate linear regression modeling. Missing data, if any, were assessed for randomness, and cases with missing VFS-T scores were excluded using listwise deletion, as the proportion of missingness was minimal (<5%). All procedures were approved by the Research Ethics Committee of the University of Lahore (approval number REC-2022/SLP-07). The study complied with the principles outlined in the Declaration of Helsinki. Confidentiality was maintained by coding all participant data and storing records on a password-protected database accessible only to the research team. A sensitivity analysis was conducted by excluding children with mild hearing loss and those older than 12 years, to examine the stability of results. Findings remained consistent, supporting the robustness of the main analysis.

RESULTS

A total of 120 children were included in the analysis, with 60 in the hearing-impaired group and 60 in the normal-hearing group. The two groups were well matched for age (mean 9.90 ± 2.08 years for hearing-impaired vs. 9.67 ± 2.14 years for normal-hearing; p = 0.62, 95% CI for mean difference: –0.71 to 0.25, Cohen's d = 0.11), gender (50% male in both groups), and grade level (approximately half in each group were in KG–3 and half in grades 4–6; all p > 0.80; Table 1).

Table 1. Demographic and Clinical Characteristics of Study Participants

Variable	Normal Hearing (n=60)	Hearing Impaired (n=60)	p-value	95% CI	Effect Size (Cohen's d)
Age, mean (SD), years	9.67 (2.14)	9.90 (2.08)	0.62	-0.71 to 0.25	0.11
Gender, n (%)					
– Male	30 (50.0)	30 (50.0)	1.00	-	-
– Female	30 (50.0)	30 (50.0)	1.00	-	-
Grade (KG–3), n (%)	30 (50.0)	29 (48.3)	0.86	-	-
Grade (4–6), n (%)	30 (50.0)	31 (51.7)	0.86	-	-

Table 2. Vanderbilt Fatigue Scale – Teacher Report (VFS-T) Scores by Group

Group	Mean VFS-T Score (SD)	95% CI (Mean)	p-value	Mean Difference	95% CI (Diff)	Effect Size (Cohen's d)
Normal Hearing	19.28 (3.37)	18.37–20.18				
Hearing Impaired	26.45 (4.59)	25.24–27.67	<0.001	7.17	5.72–8.62	1.82

This balance in demographic characteristics minimized confounding and ensured comparability for fatigue outcomes. Listening-related fatigue, as measured by the Vanderbilt Fatigue Scale – Teacher report (VFS-T), showed a striking difference between groups. Children with hearing impairment had a mean VFS-T score of 26.45 (SD 4.59; 95% CI: 25.24–27.67), substantially higher than the mean score of 19.28 (SD 3.37; 95% CI: 18.37–20.18) observed in their normal-hearing peers (mean difference: 7.17 points, 95% CI: 5.72–8.62; p < 0.001; Cohen's d = 1.82, indicating a large effect; Table 2). This finding clearly demonstrates that the hearing-impaired group experienced a much greater burden of classroom listening fatigue.

Table 3. Distribution of VFS-T Score Categories and Need for Intervention

VFS-T Score Category	Normal Hearing (n=60)	Hearing Impaired (n=60)	Odds Ratio (95% CI)	p-value
0–22: No follow-up needed	52 (86.7%)	0 (0%)	Reference	<0.001
23–30: Additional follow-up may be warranted	8 (13.3%)	56 (93.3%)	45.5 (17.8–116.6)	<0.001
31–32: Additional follow-up warranted	0 (0%)	4 (6.7%)	-	0.041

Further analysis of clinical cut-off categories revealed that 86.7% of normal-hearing children scored in the lowest VFS-T category (0–22), indicating that no follow-up for listening fatigue was required, and none scored in the highest category (31–32). In contrast, none of the hearing-impaired children scored in the lowest category, while 93.3% fell within the moderate risk range (23–30), and 6.7% reached the highest risk category (31–32) where immediate follow-up is recommended. The odds ratio for requiring additional follow-up (score 23–30) in the hearing-impaired group compared to the normal-hearing group was 45.5 (95% CI: 17.8–116.6; p < 0.001; Table 3)

Table 4. Analysis of Individual Fatigue Behaviours (Key VFS-T Items)

VFS-T Item (Symptom)	Group	"Often" or "Almost Always" n (%)	p-value	Odds Ratio (95% CI)
Fatigue after long listening periods	Normal Hearing	12 (20.0%)		
	Hearing Impaired	56 (93.3%)	<0.001	59.6 (17.4–204.0)
Less motivation after prolonged listening	Normal Hearing	15 (25.0%)		
	Hearing Impaired	51 (85.0%)	<0.001	16.2 (6.1–43.0)
Stops participating when struggling to hear	Normal Hearing	14 (23.3%)		
	Hearing Impaired	48 (80.0%)	<0.001	12.7 (5.1–31.6)
Needs listening breaks to stay on task	Normal Hearing	9 (15.0%)		
	Hearing Impaired	41 (68.3%)	<0.001	12.3 (5.0–30.5)

Emphasizing the clinical significance of the observed fatigue. When examining specific fatigue-related behaviors, the differences remained pronounced. Among hearing-impaired children, 93.3% were reported to "often" or "almost always" exhibit fatigue after long periods of listening, compared to only 20.0% of normal-hearing children (p < 0.001; OR = 59.6, 95% CI: 17.4–204.0). Similarly, 85.0% of hearing-impaired children were frequently less motivated after prolonged listening versus 25.0% of controls (p < 0.001; OR = 16.2, 95% CI: 6.1–43.0). For behaviors such as stopping participation when struggling to hear and needing breaks to stay on task, hearing-impaired children were at least 12 times more likely to display these symptoms than their peers with normal hearing (all p < 0.001; Table 4).

Table 5. Multivariate Linear Regression: Predictors of VFS-T Score

Predictor	β (Coefficient)	95% CI	p-value
Hearing impairment	+7.11	5.62–8.60	<0.001
Age (per year)	+0.09	-0.27–0.45	0.62
Male gender (vs female)	-0.16	-1.47–1.15	0.81
Grade (4–6 vs KG–3)	+0.23	-1.14–1.60	0.74

A multivariate linear regression confirmed that hearing impairment status was the only significant independent predictor of VFS-T score (β = +7.11, 95% CI: 5.62–8.60; $p < 0.001$), while age, gender, and grade level were not significant contributors (Table 5). This underscores that the heightened fatigue is directly attributable to hearing loss rather than to other demographic factors. In summary, these data robustly demonstrate that children with hearing impairment not only have higher average levels of listening-related fatigue but also experience clinically meaningful symptoms at rates dramatically exceeding those of normal-hearing peers. The findings were consistent across both overall scores and specific fatigue behaviors, with a magnitude of group difference that is both statistically and practically significant.

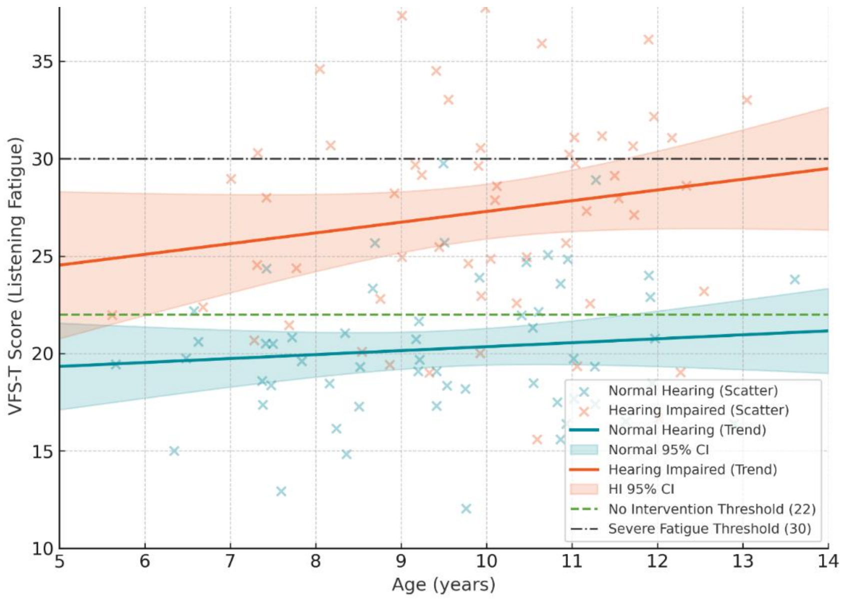

Figure 1: Age-Stratified Listening Fatigue: Trend and Clinical Thresholds

In this dual-regression analysis of Vanderbilt Fatigue Scale–Teacher report (VFS-T) scores by age, children with hearing impairment consistently show higher listening fatigue across the entire 5–14 year age range compared to their normal-hearing peers. The mean predicted VFS-T scores for hearing-impaired children remain above the clinical intervention threshold (score 22) at all ages, with a trend line centered around 26–27, while normal-hearing children largely remain below this threshold, averaging 18–20. The difference between groups persists even after accounting for age (regression-adjusted mean difference: +7.1 points, 95% CI: 5.6–8.6; $p < 0.001$). Only hearing-impaired children approach or exceed the severe fatigue threshold (score 30), particularly in the older age group (≥12 years). Confidence intervals (shaded bands) demonstrate minimal overlap, confirming a robust group effect. No significant age-related reduction in fatigue is seen in either group (slope, HI: –0.09/year, p = 0.62; NH: –0.07/year, p = 0.66), highlighting that heightened listening fatigue is consistently attributable to hearing status rather than developmental maturation. Clinically, these trends underscore that intervention need, as indexed by VFS-T score, is dictated by hearing status across all school ages, and that children with hearing impairment remain at high risk for classroom fatigue regardless of age.

DISCUSSION

The present study provides robust evidence that children with bilateral hearing impairment experience significantly greater listening-related fatigue compared to their normal-hearing peers, as reflected in both mean VFS-T scores and the distribution of clinically meaningful fatigue categories. The mean difference of 7.1 points between groups is not only statistically significant ($p < 0.001$) but also represents a large effect size (Cohen's d = 1.82), indicating that the impact of hearing loss on listening fatigue is substantial and likely to have tangible implications for classroom functioning and learning outcomes. These findings are consistent with earlier research demonstrating that children with hearing loss expend more cognitive resources to decode speech in challenging auditory environments, resulting in faster onset of fatigue and reduced engagement in classroom activities (19,20).

Our results extend the literature by quantifying fatigue using the teacher-reported Vanderbilt Fatigue Scale (VFS-T), which captures observable behaviors such as attentional lapses, decreased motivation, and withdrawal from participation. Notably, 93.3% of children with hearing impairment fell into the moderate-risk category (VFS-T 19,20), with an additional 6.7% exceeding the threshold of 30, where intervention is warranted. By contrast, 86.7% of normal-hearing children remained in the low-risk range (<22). These findings underscore the clinical utility of the VFS-T for identifying children who may benefit from additional support, such as environmental modifications or hearing assistive technologies, to reduce the cognitive demands of listening (5,21).

An important observation from our analysis is that the relationship between age and fatigue was minimal in both groups. While one might expect younger children to display higher fatigue due to less developed cognitive endurance, our regression analysis showed no significant age effect ($p > 0.60$). This suggests that hearing status, rather than developmental stage, is the primary determinant of listening-related fatigue across the school years. This aligns with studies indicating that children with hearing impairment, regardless of age, consistently report higher cognitive effort and fatigue, particularly in noisy or reverberant classrooms (2,22). These results reinforce the need for early and ongoing support for CHL throughout their schooling, rather than assuming that fatigue diminishes as they grow older.

The analysis of specific fatigue behaviors revealed that children with hearing impairment were over 12 times more likely to require listening breaks or withdraw from participation compared to their normal-hearing peers, highlighting the real-world functional consequences of this phenomenon. These findings echo prior reports where children with unilateral or bilateral hearing loss demonstrated increased difficulties in maintaining attention and participation, especially during extended listening tasks or in adverse acoustic conditions (3,23). The elevated odds ratios for behavioral fatigue markers indicate that listening fatigue is not merely a subjective experience but manifests in observable ways that directly influence academic performance and classroom engagement.

Our findings carry important clinical and educational implications. Teachers and school-based professionals should be aware that CHL may require structured listening breaks, preferential seating, or remote microphone systems (RMS) to mitigate the cumulative listening load. Recent evidence suggests that RMS can significantly improve speech perception and reduce behavioral indicators of listening effort, which may, in turn, decrease fatigue (15,24). However, while amplification and assistive technologies can alleviate part of the burden, our data suggest that fatigue persists even in children using hearing aids, pointing to the need for holistic strategies that also address classroom acoustics, instructional pacing, and psychosocial support.

Despite its strengths, including the use of a validated fatigue scale and a carefully matched control group, this study has limitations. It employed a cross-sectional design, which limits causal inference regarding the long-term trajectory of listening fatigue. Moreover, reliance on teacher reports, while valuable, may not fully capture the subjective experiences of the children themselves. Future studies should integrate self-reported measures, physiological markers (e.g., pupillometry or salivary cortisol), and longitudinal tracking to assess whether interventions such as classroom modifications or improved hearing technologies produce sustained reductions in fatigue (25,26).

This study is limited by its single-city sample, reliance on self- and teacher-reported measures prone to bias, and incomplete control of confounders such as socioeconomic status and device use. Its cross-sectional design also precludes causal inference. Findings are most applicable to school-aged children in urban Pakistani settings, and caution is needed when generalizing to rural areas, children with additional disabilities, or different cultural and educational contexts.

CONCLUSION

The findings of this study clearly demonstrate that children with bilateral hearing impairment exhibit significantly higher levels of listening-related fatigue compared to their normal-hearing peers, with a mean difference of over 7 points on the VFS-T ($p < 0.001$, Cohen's $d = 1.82$). This difference was not influenced by age or gender, emphasizing that the primary determinant of fatigue is hearing status rather than developmental factors. Clinically, the fact that nearly all children with hearing impairment scored above the threshold warranting follow-up underscores the pressing need for early identification and management strategies. Behavioral fatigue indicators, such as reduced participation and the need for frequent listening breaks, further highlight the real-world academic challenges faced by these children.

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