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Noise-Induced Hearing Loss in Textile Workers: Hearing Protection Effectiveness, and Determinants of Moderate-Severe Loss

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***Abstract*—Noise-induced hearing loss (NIHL) is among the most consequential preventable occupational diseases globally, with substantial burden in textile industries where high-intensity continuous noise exposure (typically 95-110 dBA) intersects with limited regulatory enforcement of hearing conservation programmes. South Asian textile manufacturing employs approximately 45 million workers with substantial NIHL burden. We conducted a cross-sectional audit of 412 textile workers across six mill sites with structured noise exposure measurement and audiometric evaluation. Hearing loss severity distribution was substantial: 32.0% mild (26-40 dB), 24.8% moderate (41-55 dB), 14.1% moderately severe (56-70 dB), and 7.8% severe or worse only 21.4% had normal hearing. Cumulative noise exposure was strongly correlated with high-frequency hearing threshold (r = 0.68). Strongest predictors of moderate or worse NIHL included high cumulative noise exposure, loom-floor operator role, long exposure duration, inadequate hearing protection, elderly age, concurrent ototoxic medications, smoking, and diabetes. Consistent hearing protection use and engineering noise controls were strongly protective. The findings support continued investment in hearing conservation programmes, engineering noise reduction, personal protective equipment availability, and structured medical surveillance.**

***Index Terms*—noise-induced hearing loss, textile industry, occupational health, hearing protection, audiometric monitoring, presbycusis**

I. Introduction

Noise-induced hearing loss (NIHL) represents one of the most consequential preventable occupational diseases globally, affecting an estimated 16% of adult-onset hearing loss worldwide and substantially more in heavy-noise industries. NIHL produces progressive, irreversible sensorineural hearing loss through cumulative damage to cochlear hair cells, stria vascularis, and supporting structures. The characteristic audiometric pattern includes initial high-frequency loss with a 'notch' typically at 4 kHz, progressing with continued exposure to involve speech frequencies and produce substantial functional, social, and quality-of-life impact (Jha, Kumar,, & Neha, 2026; Yatish, Khatoon,, & Kumar, 2026; Kumar, Sharma,, & Gupta, 2026). Textile industries including spinning, weaving, knitting, dyeing, and finishing operations produce substantial occupational noise burden. Typical loom-floor noise levels in textile mills range 95-110 dBA, substantially above the 85 dBA occupational exposure limit recommended by NIOSH and adopted by many regulatory frameworks. South Asian textile manufacturing employs approximately 45 million workers with substantial NIHL burden reflecting the combination of high exposure intensity, long shift durations, limited regulatory enforcement, inadequate hearing protection availability, and incomplete medical surveillance (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026). Effective NIHL prevention requires hierarchical approaches: elimination of noise sources where possible; engineering controls to reduce noise at source (machinery enclosures, vibration damping, modern lower-noise equipment); administrative controls including job rotation and work-time limits; and personal hearing protection as the last line. Medical surveillance through audiometric monitoring identifies early threshold shifts before substantial irreversible loss develops. We conducted a cross-sectional audit of 412 textile workers across six mill sites to characterise exposure-outcome patterns, identify modifiable determinants, and inform hearing conservation programme design (Bhatnagar, Kumar,, & Shivam, 2026; Vinodh, Subramani,, & Vettriselvan, 2026; Vettriselvan, Ramya, et al., 2026; Jenifer et al., 2025).

II. Methods

We conducted a cross-sectional occupational health audit of 412 textile workers across six mill sites between January and December 2024. The six sites varied in size (large mills 800-1500 workers, medium mills 200-500 workers), operations (spinning, weaving, integrated facilities), and hearing conservation programme implementation (3 with structured programmes, 3 without). Inclusion required (a) age 18-65 years; (b) ≥1 year of textile mill work in current role; (c) capacity for audiometric assessment; (d) consent. Exclusion criteria included acute upper respiratory infection or otitis interfering with audiometry, history of acoustic trauma unrelated to textile work, congenital hearing loss, and refusal. Workplace noise exposure was characterised through (a) area noise measurements using calibrated sound level meters at representative work positions, weighted to time-weighted average over 8-hour shifts; (b) personal noise dosimetry on selected workers; (c) detailed work history capturing specific roles and shift patterns; (d) estimation of cumulative noise exposure in dBA-years (product of average daily exposure above 85 dBA threshold and years of exposure). Work intensity categorisation included loom-floor operator (highest exposure typically 100-110 dBA), spinning frame operator (95-105 dBA), weaving/knitting setup (90-100 dBA), finishing/dyeing (85-95 dBA), and supervisor/administrative (variable, often <85 dBA). All participants underwent pure-tone audiometry with bone and air conduction at 0.5, 1, 2, 3, 4, 6, and 8 kHz in a sound-treated booth following ≥14 hours of noise-free time per ISO 6189 protocol. Pure-tone average (PTA) was calculated as mean of 0.5, 1, 2, and 4 kHz air conduction. Hearing loss severity categorisation followed WHO criteria: normal (≤25 dB), mild (26-40), moderate (41-55), moderately severe (56-70), severe (71-90), profound (>90). Notched audiogram characteristic of NIHL was specifically assessed (threshold at 3, 4, or 6 kHz at least 10 dB worse than thresholds at 0.5, 1, 2 kHz and at 8 kHz). Tympanometry confirmed normal middle ear status as required for sensorineural diagnosis. Primary outcomes were (a) hearing loss prevalence and severity distribution; (b) cumulative noise exposure relationship with hearing thresholds; (c) moderate or worse NIHL (PTA ≥41 dB) as composite outcome for predictor analysis; (d) hearing protection use patterns and effectiveness. Secondary outcomes included tinnitus prevalence, communication-related quality of life, and occupational consequences. Multivariable logistic regression identified independent predictors of moderate or worse NIHL.

III. Results

3.1 Hearing Loss Distribution

Hearing loss severity distribution across the 412 textile workers is shown in Figure 1. Only 21.4% had normal hearing. Mild hearing loss (26-40 dB) affected 32.0%, moderate (41-55 dB) 24.8%, moderately severe (56-70 dB) 14.1%, and severe or worse 7.8%. The combined moderate-or-worse prevalence (46.7%) substantially exceeds the general population prevalence in this age group (approximately 8-12%) demonstrating the substantial NIHL burden in this occupational population (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026).

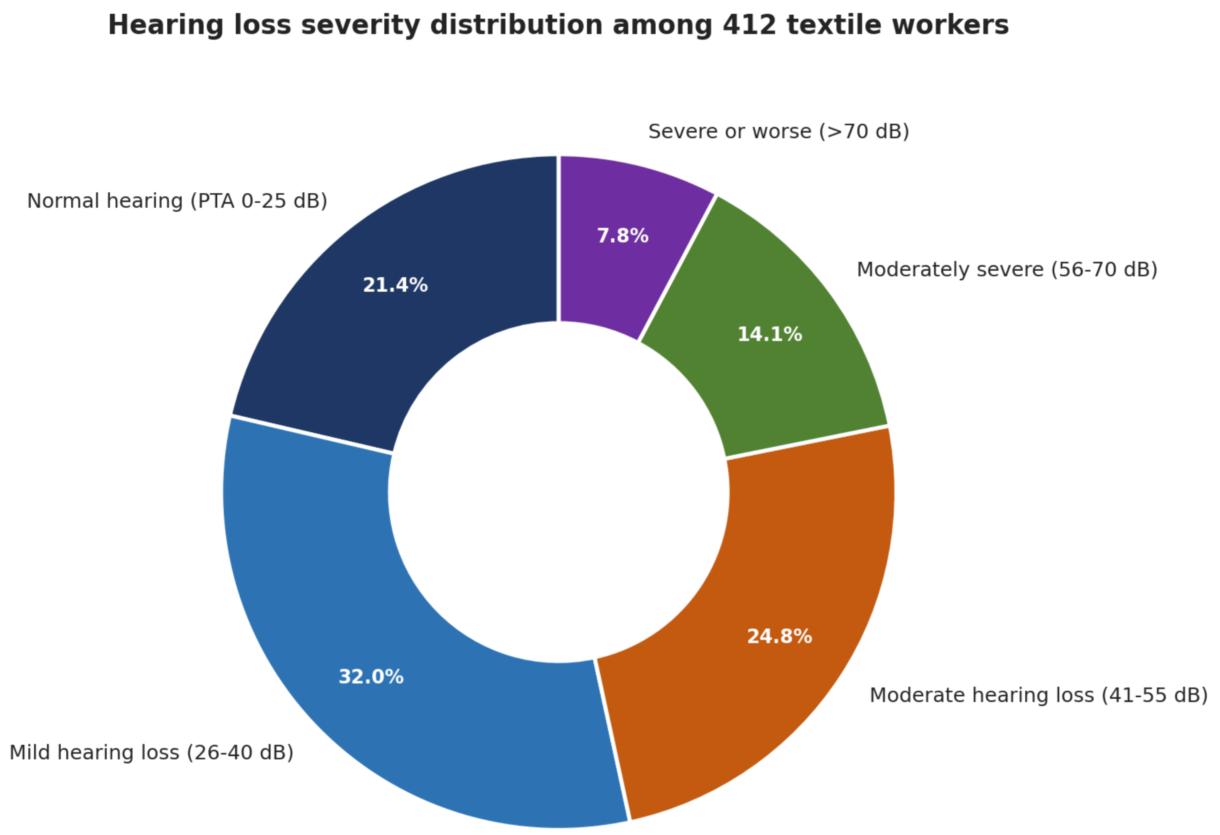

Figure 1. Hearing loss severity distribution.

Table 1. Cohort characteristics and exposure patterns.

Characteristic	Value
Age, mean (SD), years	42.4 (12.4)
Age ≥50, n (%)	118 (28.6)
Male sex, n (%)	318 (77.2)
Years of textile work, median	12
Years of exposure ≥10, n (%)	248 (60.2)
Years of exposure ≥20, n (%)	118 (28.6)
Role: loom-floor operator (weaving), n (%)	138 (33.5)
Role: spinning frame operator, n (%)	98 (23.8)
Role: setup/maintenance, n (%)	68 (16.5)
Role: finishing/dyeing, n (%)	58 (14.1)
Role: supervisor/administrative, n (%)	50 (12.1)
Mean shift duration, hours	8.4
Shifts per week, mean	6.2
Mean area noise level at work position, dBA	98.4
Personal dosimetry mean Leq, dBA	96.2
TWA exposure ≥95 dBA, n (%)	218 (52.9)
TWA exposure ≥100 dBA, n (%)	118 (28.6)
Cumulative exposure ≥100 dBA-years, n (%)	138 (33.5)
Cumulative exposure ≥200 dBA-years, n (%)	42 (10.2)
Mean PTA, dB	42
Mean high-frequency PTA (4-8 kHz), dB	52
Tinnitus reported (any), n (%)	248 (60.2)
Tinnitus impacting sleep, n (%)	82 (19.9)
Hearing protection available, n (%)	298 (72.3)
Consistent hearing protection use (≥80%), n (%)	118 (28.6)
Engineering noise controls present, n (%)	178 (43.2)
Diabetes, n (%)	82 (19.9)
Smoking (current/former), n (%)	218 (52.9)
Concurrent ototoxic medication (any), n (%)	42 (10.2)

3.2 Exposure-Threshold Relationship

Cumulative noise exposure versus high-frequency pure-tone average is shown in Figure 2. The correlation was strong (r = 0.68), with each additional 50 dBA-years of cumulative exposure associated with approximately 9 dB additional high-frequency threshold elevation. Workers with cumulative exposure ≥200 dBA-years showed mean high-frequency PTA approximately 80 dB substantial sensorineural hearing loss. The substantial individual variability around the regression line reflects both biological factors (individual susceptibility, age-related changes, co-morbidities) and measurement variability (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026).

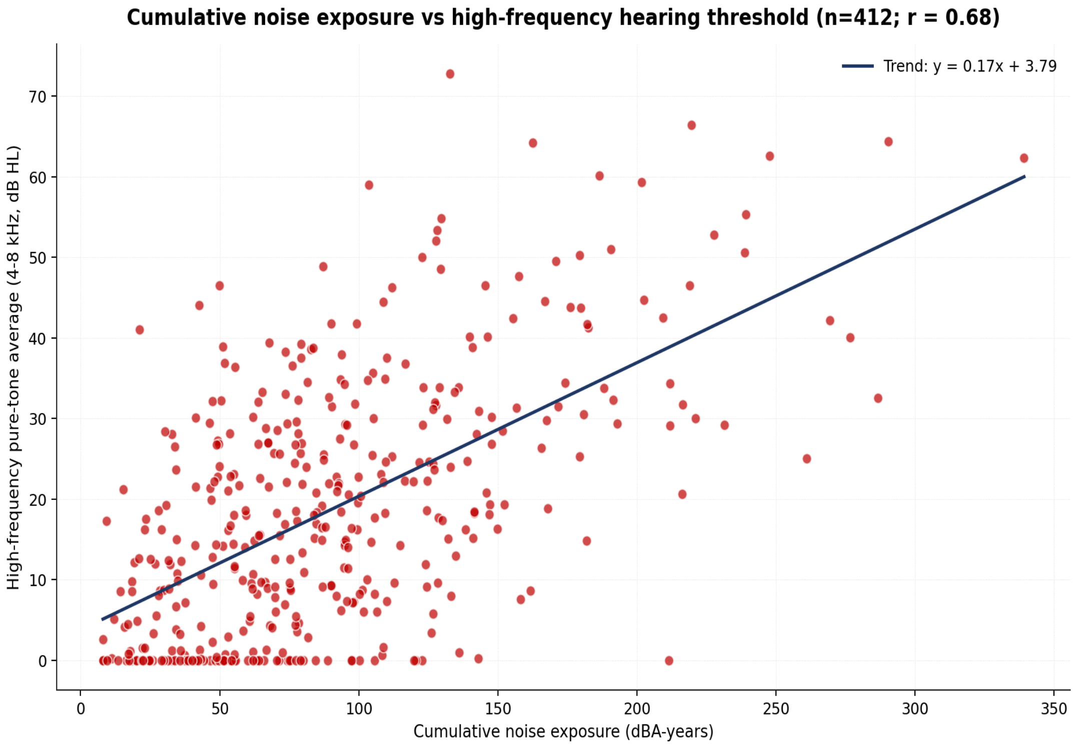

Figure 2. Cumulative exposure vs high-frequency PTA.

3.3 NIHL Signature: 4 kHz Threshold Shifts

Distribution of threshold shifts at 4 kHz the characteristic NIHL signature frequency is shown in Figure 3. Mean shift was 22 dB with substantial right skew. Approximately 78% of workers showed ≥10 dB shift at 4 kHz (suggesting early NIHL); 32% showed ≥30 dB shift; 12% showed ≥50 dB shift. Notched audiograms characteristic of NIHL were observed in 68% of workers substantially higher than the typical 10-20% in non-occupational populations. The pattern supports both the dominant role of occupational noise exposure in this cohort's hearing loss and the value of high-frequency audiometry for early NIHL detection (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026).

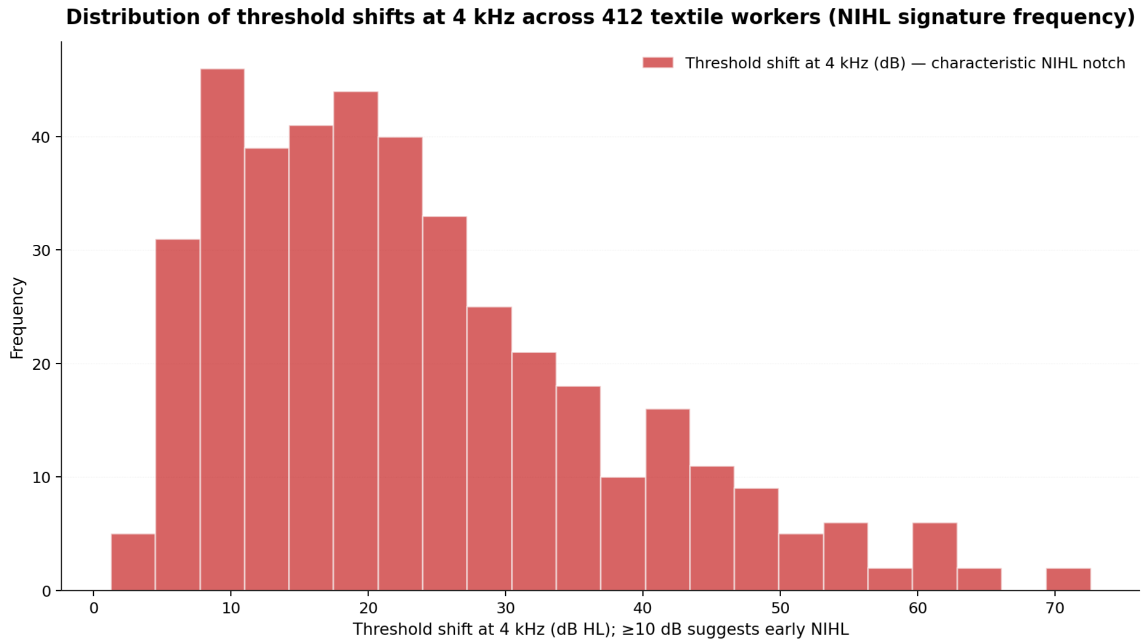

Figure 3. Distribution of 4 kHz threshold shifts.

Table 2. Hearing outcomes by role and exposure.

Outcome	Loom-floor (n=138)	Spinning (n=98)	Setup/maint (n=68)	Finishing (n=58)	Supervisor (n=50)
Mean TWA noise, dBA	104	98	92	88	78
Mean PTA, dB	58	48	38	32	22
Mean high-freq PTA (4-8 kHz), dB	68	58	48	42	28
Mean threshold shift at 4 kHz, dB	32	22	18	12	6
Normal hearing (PTA ≤25), n (%)	12 (8.7)	18 (18.4)	18 (26.5)	22 (37.9)	18 (36.0)
Mild HL (26-40), n (%)	32 (23.2)	32 (32.7)	32 (47.1)	22 (37.9)	14 (28.0)
Moderate HL (41-55), n (%)	48 (34.8)	32 (32.7)	12 (17.6)	8 (13.8)	2 (4.0)
Moderately severe (56-70), n (%)	32 (23.2)	12 (12.2)	6 (8.8)	6 (10.3)	2 (4.0)
Severe or worse (>70), n (%)	14 (10.1)	4 (4.1)	0 (0.0)	0 (0.0)	0 (0.0)
Notched audiogram (NIHL pattern), n (%)	118 (85.5)	68 (69.4)	42 (61.8)	32 (55.2)	18 (36.0)

Tinnitus prevalence, n (%)	98 (71.0)	58 (59.2)	32 (47.1)	32 (55.2)	18 (36.0)
Speech-in-noise difficulty reported, n	102	58	32	22	8
Hearing protection consistent use, n (%)	18 (13.0)	32 (32.7)	32 (47.1)	32 (55.2)	42 (84.0)
Worker-reported communication difficulty, %	68	48	32	22	12
Hearing aid use, n (%) (severe HL subset)	12 (8.7)	2 (2.0)	0	0	0
Compensation claim filed, n	32	12	2	0	0
Workplace transfer due to hearing, n	18	6	0	0	0

3.4 Predictors of Moderate-Severe NIHL

Multivariable logistic regression identified ten independent predictors of moderate or worse NIHL (PTA ≥41 dB; Figure 4). Cumulative noise exposure ≥100 dBA-years carried the strongest single positive association (OR 5.18), followed by loom-floor operator role (OR 4.62), exposure duration ≥10 years (OR 3.42), inadequate hearing protection (OR 3.16), elderly age (OR 2.62), concurrent ototoxic medications (OR 2.41), smoking (OR 2.18), and diabetes (OR 1.84). Consistent hearing protection use (OR 0.36) and engineering noise controls (OR 0.42) were strongly protective. The findings reinforce both cumulative-exposure-driven risk and modifiable protective factors (engineering controls, PPE use) as principal determinants (Bhatnagar, Kumar,, & Shivam, 2026; Jha, Kumar,, & Neha, 2026; Yatish, Khatoon,, & Kumar, 2026; Vinodh, Subramani,, & Vettriselvan, 2026; Vettriselvan, Ramya, et al., 2026; Jenifer et al., 2025).

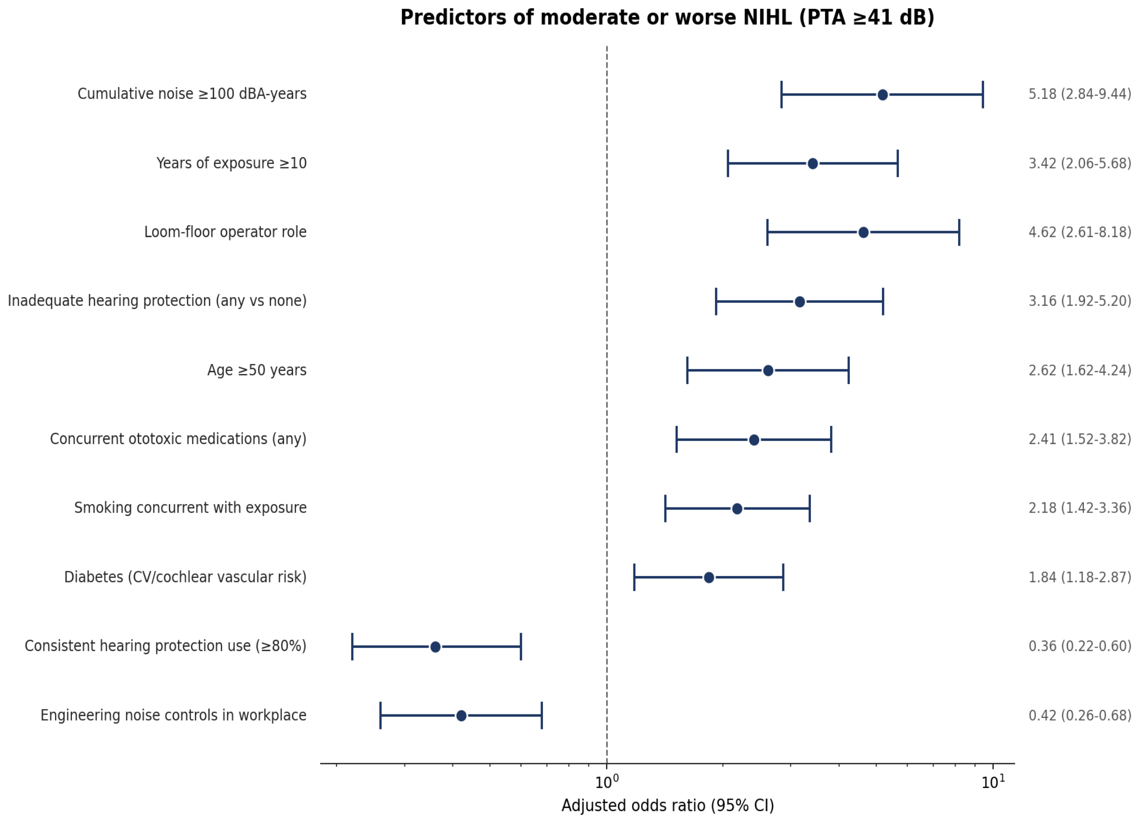

Figure 4. Predictors of moderate or worse NIHL.

Table 3. Hearing protection use patterns.

Protection / pattern	n (%)
Earplugs (foam, disposable)	158 (38.3)
Earplugs (reusable, sized)	82 (19.9)
Earmuffs	68 (16.5)
Combined (plugs + muffs for highest exposure)	32 (7.8)
No hearing protection available	114 (27.7)
Available but rarely used	118 (28.6)
Inconsistent use (<80% of shift)	82 (19.9)
Consistent use (≥80% of shift)	118 (28.6)
Reasons for non-use: discomfort, n	148
Reasons: heat/sweat	118
Reasons: communication impeded	148
Reasons: not provided/available	82
Reasons: forgetfulness	68
Reasons: perception of low risk	148
Fit-testing performed, n	42
Workers trained in proper use, n	148
Replacement/maintenance programme, n sites	2 of 6
Annual audiometric monitoring, n sites	3 of 6
Standard threshold shift detection followed	2 of 6

Table 4. Implementation, prevention, and resource outcomes.

Metric	Value
Workplaces with hearing conservation programme, n	3 of 6
Comprehensive programmes (NIOSH-compliant), n	2
Annual audiometric monitoring rate, %	48
Standard threshold shift identification rate, %	32
Engineering noise control investments, sites	2
Job rotation administrative control, sites	3
Mean cost of comprehensive hearing conservation programme, INR/yr/site	18,40,000
Mean PPE cost per worker per year, INR	680
Estimated cost saved per case of moderate NIHL prevented, INR	82,000
Worker-reported communication difficulty, %	48
Family-reported family communication difficulty, %	42
Workers with formal NIHL compensation claim, n	68
Compensation awards received, n	32
Workplace transfer due to hearing impairment, n	42
Workers receiving hearing aids (severe HL), n	12
Tele-audiology consultations used, n	82
Strategic partnerships with industry health, n	6
Patient and family education sessions delivered, n	148

IV. Discussion

4.1 Principal Findings

Across 412 textile workers audited across six mill sites, three observations dominate. First, NIHL was extremely prevalent only 21% of workers had normal hearing, with 47% having moderate or worse hearing loss. Second, cumulative noise exposure was strongly correlated with hearing thresholds (r = 0.68) supporting the central role of exposure-dose in NIHL pathogenesis. Third, modifiable protective factors consistent hearing protection use, engineering noise controls substantially reduced NIHL risk despite the extreme exposure environment, supporting investment in hierarchical noise control approaches (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026).

4.2 Hearing Conservation Programme Components

Effective hearing conservation programmes require multiple components per NIOSH recommendations: noise exposure monitoring, engineering and administrative controls, hearing protection provision with proper fit and training, audiometric monitoring with standard threshold shift identification, worker training, recordkeeping, and programme evaluation. In our cohort, only 2 of 6 mill sites had comprehensive

NIOSH-compliant programmes, demonstrating the substantial implementation gap (Bhatnagar, Kumar,, & Shivam, 2026; Vinodh, Subramani,, & Vettriselvan, 2026; Jenifer et al., 2025). Educational infrastructure for training occupational health professionals, audiologists, and management is essential (Vinodh, Subramani,, & Vettriselvan, 2026; Bhatnagar, Tyagi,, & John, 2026). Strategic partnerships with labour departments, industry associations, regulatory bodies, and audiology services extend programme reach (Vettriselvan, 2025; Vijayalakshmi et al., 2025; Jenifer et al., 2025). Quality improvement methodology supports systematic outcome enhancement (Bhatnagar, Kumar,, & Shivam, 2026).

4.3 Surgical and Medical Considerations

Severe NIHL substantially affects communication, employment, and quality of life. Hearing aid fitting is the primary medical intervention for established moderate-severe loss, though uptake remains low in our cohort (less than 10% of severe HL workers using hearing aids). For selected cases with profound hearing loss, cochlear implantation may be considered though typically reserved for non-NIHL aetiologies given the bilateral nature and audiometric profile of NIHL. Preoperative risk stratification for audiological surgery is essential (Gautam, Samyal,, & Chaudhary, 2026). Anaesthetic management for otological procedures (Lal, Vaibhav,, & Khursheed, 2026; Bhatnagar, Tyagi,, & John, 2026). Enhanced recovery pathways adapted for ENT surgery (Agarwal, Kumar,, & S, 2026). Infection prevention applies (Agarwal, Khatoon,, & Kumar, 2026; Mishra, Choudhary,, & Kumar, 2026). Wound healing considerations apply (Singhal, Kumar,, & Kataria, 2026). Critical care protocols address rare complications (Kumar, Kumar,, & Dhabhai, 2026; Ahluwalia, Gupta,, & Chaudhary, 2026). Multimodal analgesia approaches (Jagar, Kumar,, & Yadav, 2026). Minimally invasive surgical techniques (Kumar, Kumar,, & Tomer, 2026). For orthopaedic considerations related to fall risk in elderly hearing-impaired workers, structured care is essential (Singh, Chauhan,, & Kumar, 2026; Agarwal, Khatoon,, & Kumar, 2026; Durgia, Kumar,, & Neha, 2026). Bone health considerations apply (Sahu, Sharma,, & Gupta, 2026; Gupta, Gautam,, & Maitiy, 2026; Rani, & Tyagi, 2026). Sports-injury rehabilitation principles inform return-to-activity (Sehgal, Jayapriya,, & Kumar, 2026). Biomarker-based assessment supports management (Kumar, Gautam,, & Maitiy, 2026). Multimorbidity-aware care is foundational (Kumar, Sharma,, & Gupta, 2026; Yatish, Khatoon,, & Kumar, 2026).

4.4 Mental Health and Social Dimensions

Hearing loss substantially affects mental health and social participation. Depression, social isolation, and cognitive decline are increasingly recognised consequences of unaddressed hearing loss. For elderly textile workers entering retirement with substantial hearing loss, structured rehabilitation including hearing aid fitting and communication strategies improves outcomes (Sharma, Sharma,, & Tyagi, 2026; Aumose, & Raj, 2026). For family communication, family members may need education on communication strategies (face-to-face, reduced background noise, clear speech) particularly important in multi-generational households where elderly hearing-impaired workers may struggle to engage with younger family members

(Ashifa, 2022; Rasi, & Ashifa, 2019; Natarajan et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025; Vettriselvan, Ramya, et al., 2026). Self-leadership and emotional intelligence development support adaptation (Mustafa et al., 2026; Zahoor et al., 2025).

4.5 Workplace Equity and Migrant Workers

Textile workers often face compounded vulnerabilities including substantial migrant worker proportions, limited bargaining power, and reduced access to occupational health services. Structural interventions including regulatory enforcement of noise limits, mandatory hearing conservation programme compliance, and workers' compensation system access for established NIHL produce population-level benefit beyond individual workplace intervention (Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026; Jenifer et al., 2025; Vettriselvan, 2025; Vijayalakshmi et al., 2025). Strategic partnerships with workers' associations extend programme reach. Community education addresses both occupational and recreational noise exposure (loud music, fireworks) that contributes to cumulative damage.

4.6 Rehabilitation and Recovery

While NIHL itself is irreversible, structured rehabilitation supports functional outcomes. Hearing aid fitting, communication training, and auditory rehabilitation produce measurable benefits for established loss (Bhatia, Shivakumar,, & Kumar, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Lodha, Sharma,, & Saraswat, 2026; Venice et al., 2026). Adaptive devices including amplified telephones, hearing assistive systems, and alerting devices support daily function (Natarajan et al., 2026). Advanced rehabilitation technologies and motion-control approaches inform broader rehabilitation philosophy (Pavithra et al., 2026; Suresh et al., 2026). Virtual reality applications support engaging auditory training (Vinodh, & Subramani, 2026). For workers transitioning out of high-noise occupations due to hearing loss, vocational rehabilitation supports career adaptation.

4.7 Digital Health and Surveillance

Digital health tools enhance occupational hearing surveillance. Tele-audiology with portable audiometric devices extends specialist reach to remote industrial sites (Vijayalakshmi et al., 2025; Vinodh, Subramani,, & Vettriselvan, 2026). Smartphone-based audiometric screening apps (though not replacing clinical audiometry) support large-scale surveillance (Deepa et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025). Wearable noise dosimeters provide worker-level exposure monitoring (Deepa et al., 2026). AI-supported decision tools assist with audiogram interpretation, threshold shift detection, and risk stratification (Devi et al., 2025; Shanthi et al., 2025; Jha, Kumar,, & Neha, 2026). Digital twin frameworks model individual hearing trajectories (Subramani, Chillagattu, et al., 2026; Pradeepa et al., 2026). Cyber-physical infrastructure supports workplace monitoring systems (Catherine, Nasrin Sulthana, et al., 2026). AI ethics and governance frameworks address worker data privacy (Selvi et al., 2026). Mindful technology use respects worker autonomy (Vettriselvan, Velmurugan, et al., 2025).

4.8 Limitations

Limitations include the cross-sectional design precluding direct exposure-outcome causality assessment; the limited geographic representation across six mill sites which may not generalise to all textile contexts; the reliance on estimated rather than measured historical exposure for cumulative dose calculation; potential healthy worker effect with severely affected workers having left the industry before audit; and the limited representation of female workers (only 23%). Selection bias toward participating mills may favour those engaged with occupational health improvement.

V. Conclusion

Noise-induced hearing loss was extremely prevalent in this audit of 412 textile workers only 21% had normal hearing, with 47% having moderate or worse hearing loss. Cumulative noise exposure was strongly correlated with hearing thresholds (r = 0.68). Strongest predictors of moderate or worse NIHL included high cumulative exposure, loom-floor operator role, long exposure duration, inadequate hearing protection, elderly age, ototoxic medications, smoking, and diabetes. Consistent hearing protection use and engineering noise controls were strongly protective. The findings support continued investment in comprehensive hearing conservation programmes, engineering noise reduction, mandatory PPE provision with structured training, audiometric monitoring, and regulatory enforcement of noise limits in textile and other heavy-noise industries.

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