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ORIGINAL ARTICLE

A Comparative Analysis of Occupational Hearing Loss Among White- and Blue-Collar Employees in a Leading Iranian Automotive Industry

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ABSTRACT

Background: Noise-induced hearing loss (NIHL) is among the most prevalent occupational disorders in industrial settings, particularly in the automotive manufacturing sector. Despite extensive noise exposure, variability in hearing outcomes suggests the presence of multiple occupational and non-occupational contributing factors.

Purpose of the study: This study aimed to evaluate the hearing status of employees in a major automobile manufacturing company and to compare the prevalence and severity of hearing loss between noise-exposed production (blue-collar) workers and non-exposed administrative (white-collar) staff.

Methods: A cross-sectional study of 2,312 male workers (2,136 blue-collar, 176 white-collar) assessed hearing thresholds via pure-tone audiometry. Hearing loss was defined as >25 dB HL. Demographic and occupational data were analyzed using descriptive and inferential statistics.

Results: The mean age was 42.9 years. Hearing loss >25 dB HL was under 10% across all subgroups. No major differences in overall thresholds were found, though white-collar workers showed slightly greater hearing loss at select low and high frequencies, despite no occupational noise exposure. Differences were statistically, but not clinically, significant.

Conclusion: These findings suggest that occupational noise exposure alone does not fully explain hearing loss among industrial workers. Better hearing outcomes in noise-exposed blue-collar workers may reflect the effectiveness of structured hearing conservation programs and pre-employment screening. In contrast, white-collar staff may experience hearing decline from non-occupational sources. The results underscore the importance of the Healthy Worker Effect and highlight the need for future research to account for worker selection, health surveillance practices, and prior noise exposure beyond the workplace.

KEYWORDS: *Noise-induced hearing loss, Occupational exposure, Audiometry, Pure-tone, Automobile industry, Hearing conservation*

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INTRODUCTION

Noise-induced hearing loss (NIHL) is recognized as the most prevalent occupational disease worldwide, posing a significant public health challenge [1–7]. According to the World Health Organization, approximately five percent of the global population suffers from some form of hearing impairment [2]. A variety of risk factors are associated with hearing loss, including systemic conditions such as arthrodermatous diseases and diabetes mellitus; exposure to ototoxic agents and drugs; smoking; aging; environmental heat; elevated blood lipid levels; and, most prominently, prolonged exposure to high-intensity or non-Gaussian noise [2, 8, 9]. Chronic exposure to excessive noise can irreversibly damage the cochlear sensory cells, often beginning with a temporary threshold shift (TTS) and progressing to a permanent threshold shift (PTS), typically evident at frequencies between 4 and 6 kHz [3, 4]. Numerous studies across the globe have documented hearing loss among workers exposed to occupational noise [7, 10]. It is estimated that 1.3 billion individuals worldwide experience some form of NIHL [5], and occupational noise accounts for about 16% of hearing loss cases in adults [5, 6]. Prevalence estimates for hearing loss among workers vary between 7% and 21%, depending on industry and region [11]. In the United States, hearing loss is the most frequently reported occupational illness, with about 20% of the population affected [12, 13], while in the UK, NIHL comprises approximately 8% of all occupational diseases [14]. Among Chinese workers, a prevalence of 20% has been reported [15], and in Iran, meta-analyses estimate the prevalence of occupational hearing loss to range between 12.9% and 60.5%, with a pooled estimate of 34.69% [16]. In one study conducted among Iranian automotive workers with a mean age of 33.51 ± 5.35 years, the prevalence reached 60.5% [17]. In contrast, a Korean study reported a prevalence of 1.81% for hearing loss over 25 dB in automotive manufacturing workers [18].

Despite extensive documentation of NIHL prevalence globally, there remains limited understanding of how occupational role categories—particularly white-collar (office-based) versus blue-collar (manual labor) workers—differ in their exposure to noise and their respective risks for developing hearing loss, particularly within a uniform industrial context. While some studies have explored variations in hearing health outcomes between these occupational groups, most have been conducted across heterogeneous environments or industries, where confounding variables related to differing work atmospheres, job demands, and exposure levels may influence findings. The relative contribution of non-auditory factors, such as age, lifestyle habits, and comorbidities, in modulating the risk of hearing loss among different job classifications within the same industry also remains underexplored. This gap is particularly relevant in sectors like the automotive industry, which involves a wide range of operations and personnel types but often lacks role-specific health surveillance data.

Despite the widespread implementation of hearing conservation programs in industry, few studies have directly compared hearing loss patterns between white-collar and blue-collar workers within the same organizational context. This study addresses this gap by examining audiometric data from a large, demographically diverse workforce in a major Iranian automotive company. By evaluating how occupational classification and presumed noise exposure relate to hearing outcomes—while accounting for potential confounders—this research aims to improve understanding of occupational hearing risk disparities and support the development of more targeted, evidence-based preventive strategies in industrial settings.

MATERIALS AND METHODS

Study Design

This cross-sectional descriptive study was conducted in 2022 with the aim of determining the prevalence of hearing loss and comparing its distribution between white-collar and blue-collar workers employed at a major Iranian automotive manufacturing company located in Tehran. White-collar employees, representing the clerical staff at the company's headquarters, were assumed to have no occupational exposure to hazardous noise levels due to the nature of their administrative duties. In contrast, blue-collar participants were involved in production and industrial processes characterized by exposure to occupational noise, including instances in which levels may exceed permissible exposure limits.

Participants

The study population consisted of 2,312 male employees, including 2,136 industrial workers (blue-collar) exposed to manufacturing-related noise and 176 office-based staff (white-collar) without such exposure. All participants were recruited from a single automotive manufacturing company. All noise-exposed blue-collar workers were included to ensure full representation of the exposed population and to maximize statistical power. For the white-collar comparison group, a simple random sampling method was used to select 176 male office staff from the eligible non-exposed population. This subgroup was matched demographically in terms of age distribution and employment duration. A post hoc power analysis confirmed the adequacy of this sample size: assuming a small-to-moderate effect size (Cohen's d = 0.3), with $\alpha = 0.05$, the study had over 90% power to detect group differences. Participation was voluntary, and informed written consent was obtained from all individuals prior to enrollment. Data collection was conducted during a single working day using a standardized protocol implemented by trained personnel. Oversight and verification of all procedures were provided by an independent quality control and assurance team to ensure methodological rigor and data integrity.

Inclusion and Exclusion Criteria

Eligible participants were male employees aged between 18 and 60 years, actively working in either office or manufacturing roles within the company. Exclusion criteria included the occurrence of acute physical trauma to the auditory system within the past year, or unwillingness to participate or continue in the study. Individuals with a history of cancer or undergoing chemotherapy were also excluded due to potential confounding effects on auditory function.

Hearing Assessment

Pure-tone audiometric assessments were performed to determine air and bone conduction hearing thresholds at octave band frequencies of 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz using 5 dB resolution steps, as per ISO 8253-1:2010 standards. All assessments were conducted in a calibrated soundproof booth, with ambient noise levels maintained below 25 dB(A). The audiological evaluations were carried out by a certified audiologist using the Otometrics Madsen Xeta audiometer (Denmark), equipped with TDH-39P headphones. Participants were instructed to abstain from exposure to occupational or recreational loud noise for at least 16 hours prior to testing to minimize temporary threshold shifts.

Hearing Loss Indices and Classification

Hearing thresholds at each frequency were measured for both ears. The average hearing threshold across 500, 1000, 2000, and 3000 Hz was calculated for each ear. The binaural hearing threshold level was then determined using the formula: NIHL = (Better Ear × 5 + Worse Ear) ÷ 6. Hearing loss was categorized into six levels: Normal (<16 dB HL), Slight (16–25 dB HL), Mild (26–30 dB HL), Moderate (31–50 dB HL), Severe (51–70 dB HL), and Profound (>70 dB HL). Additionally, the prevalence of hearing loss was calculated based on thresholds exceeding 25 dB HL. To further differentiate between frequency-specific loss patterns, the average thresholds at 250, 500, and 1000 Hz were used to assess low-frequency hearing loss, and thresholds at 2000, 3000, 4000, 6000, and 8000 Hz were used for high-frequency hearing loss. These values were analyzed and classified in accordance with the same methodology used for the overall mean hearing threshold.

Covariates and Demographic Data

Data were collected on participants' demographic characteristics, including age, occupational history, anthropometric indices (height, weight, BMI), smoking history, and blood pressure, to assess potential confounding factors.

Anthropometric Assessment

Body weight was measured to the nearest 0.1 kg using a SECA digital scale, with participants wearing light clothing and no shoes. Standing height was recorded to the nearest millimeter using a SECA stadiometer. Body mass index (BMI) was calculated using the standard formula (weight in kilograms divided by height in meters squared), and participants were categorized as underweight, normal weight, overweight, or obese based on WHO guidelines.

Blood Pressure Measurement

Systolic and diastolic blood pressure were measured three times under standardized conditions using a calibrated mercury sphygmomanometer. Participants were seated and rested for 15 minutes prior to the first measurement. The second reading was taken 30 minutes later, and the final reading was obtained after a 2-hour interval. The mean of the three readings was used for analysis and reported to the nearest 1 mmHg.

Statistical Analysis

Descriptive statistics were used to summarize qualitative variables as frequencies and percentages, and quantitative variables were expressed as means ± standard deviation (SD). The distribution of continuous variables was assessed using the Kolmogorov–Smirnov test. For non-normally distributed data, median and range values were also reported.

Univariate associations between categorical variables were analyzed using the chi-square test. Depending on the distribution and type of data, the following tests were applied to assess differences in quantitative variables across groups: independent samples t-test, Mann–Whitney U test, analysis of variance (ANOVA), Wilcoxon signed-rank test, and Kruskal–Wallis test. Correlations between continuous variables were examined using Spearman's rank correlation coefficient. In addition, logistic regression analysis was employed to identify potential predictors of hearing loss while adjusting for relevant covariates. All statistical analyses were performed using SPSS version 24.0 (SPSS Inc., Chicago, IL, USA). A two-tailed P-value of less than 0.05 was considered statistically significant.

Ethical Considerations

This study was approved by the Ethics Committee of Tehran University of Medical Sciences under ethical code IR.TUMS.FNM.REC.1400.208. All participants provided informed written consent prior to participation. Confidentiality of personal data was rigorously maintained by anonymizing datasets through the assignment of coded identifiers, with access restricted to the research team. Participants were informed of their right to withdraw at any stage without penalty. All procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and the ethical approval granted by the institutional review board.

RESULTS

A total of 2,312 male employees participated in the present cross-sectional study, including 2,136 blue-collar workers exposed to industrial noise and 176 white-collar administrative staff with no occupational noise exposure, serving as the control group. This gender distribution reflects the male-dominant workforce of the studied automotive manufacturing facility. The overall mean age of participants was 42.9 years (SD = 5.1), with the white-collar group having a slightly higher mean age of 44.7 years compared to 42.7 years in the blue-collar group. To facilitate stratified analysis, participants were categorized into four age groups: <30, 30–39, 40–49, and ≥50 years. The majority of participants (approximately 80%) were aged 40–49 years, including 72% of white-collar and 80% of blue-collar employees.

Educational attainment varied significantly between the two groups. As summarized in Table 1, approximately 60% of white-collar employees held higher education degrees, while 33% had completed intermediate-level education. In contrast, the vast majority of blue-collar workers (84%) had intermediate-level education, and only 6% possessed higher education qualifications.

Hearing Loss Assessment

Air conduction audiometry revealed mean hearing thresholds around 15 dB across the left, right, and

Table 1. Baseline information and hearing loss of study participants and comparison of white-collar and blue-collar groups.

		Total n=2312	White Collar n=176	Blue Collar n=2136	P-value
Age	Mean ± SD	42.9 ± 5.1	44.7 ± 5.0	42.7 ± 5.1	**<0.001**
Age group n (%)	<30	96 (4.2)	2 (1.1)	94 (4.4)	<0.001
	30-39	302 (13.1)	25 (14.2)	277 (13.0)	
	40-50	1844 (79.8)	126 (71.6)	1718 (80.4)	
	>50	70 (3.0)	23 (13.1)	47 (2.2)	
Education n (%)	Illiterate	150 (6.5)	9 (5.1)	141 (6.6)	<0.001
	Elementary	70 (3.0)	4 (2.3)	66 (3.1)	
	Secondary	1851 (80.1)	59 (33.5)	1792 (83.9)	
	Higher	241 (10.4)	104 (59.1)	137 (6.4)	
NIHL AC (dB) Mean ± SD	Left ear	15.1 ± 8.6	16.7 ± 11.7	15.0 ± 8.3	0.117
	Right ear	15.0 ± 9.6	16.6 ± 13.5	14.8 ± 9.2	0.138
	Total	14.7 ± 7.4	15.9 ± 10.3	14.6 ± 7.1	0.104
NIHL BC (dB) Mean ± SD	Left ear	9.9 ± 8.4	11.2 ± 11.4	9.8 ± 8.1	0.290
	Right ear	9.7 ± 9.1	10.8 ± 12.2	9.6 ± 8.8	0.179
	Total	9.5 ± 7.1	10.4 ± 10.1	9.4 ± 6.8	0.285
hearing loss >25 dB n (%)	Left ear AC	140 (6.1)	14 (8.0)	126 (5.9)	0.150*
	Right ear AC	148 (6.4)	15 (8.5)	133 (6.2)	0.173*
	Left ear BC	67 (2.9)	9 (5.1)	58 (2.7)	0.064*
	Right ear BC	70 (3.0)	8 (4.5)	62 (2.9)	0.159*
	Both ear AC	76 (3.3)	7 (4.0)	69 (3.2)	0.357*
	Both ear BC	40 (1.7)	5 (2.8)	35 (1.6)	0.184*

NIHL: Noise Induced Hearing Loss, AC: Air conduction, BC: Bone conduction, * Fisher's Exact Test both ears, with no statistically significant differences observed between the noise-exposed (blue-collar) and non-exposed (white-collar) groups. Similarly, mean bone conduction thresholds were approximately 10 dB bilaterally, with no intergroup differences. The prevalence of hearing loss >25 dB HL (air and bone conduction combined) was consistently below 9% in all groups and comparisons, as detailed in Table 1.

Low-Frequency Hearing Loss

Table 2 presents the results for low-frequency hearing thresholds, defined as the average thresholds at 250, 500, and 1000 Hz. A statistically significant difference was found in mean air conduction thresholds between groups, with white-collar employees demonstrating slightly worse thresholds (~2 dB difference), particularly in the right ear ($p < 0.05$). No significant difference was found in low-frequency bone conduction thresholds in the left ear; however, a small but statistically significant difference was observed in the right ear ($p < 0.05$). The prevalence of low-frequency hearing loss (>25 dB HL) was also higher among white-collar employees in the right ear (air conduction), which was statistically significant. Detailed findings for both air and bone conduction, including left, right, and bilateral ear comparisons, are provided in Table 2.

High-Frequency Hearing Loss

Table 3 summarizes high-frequency hearing thresholds, assessed as the average of 2000, 3000, 4000, 6000, and 8000 Hz frequencies. No significant differences were observed in mean air or bone conduction thresholds between the exposed and non-exposed groups. However, the prevalence of high-frequency hearing loss >25 dB HL in the left ear (air conduction) was significantly higher among blue-collar workers compared to white-collar staff ($p < 0.05$). A similar pattern was noted for left ear bone conduction hearing loss prevalence, with statistically significant intergroup differences observed.

DISCUSSION

Noise-induced hearing loss (NIHL) remains one of the most prevalent occupational disorders in manufacturing industries, particularly in the automotive sector, where

Table 2. Low frequency (non-occupational frequencies) hearing loss of study participants and comparison of white-collar and blue-collar groups.

		Total n=2312	White Collar n=176	Blue Collar n=2136	P-value
NIHL AC Mean ± SD	left ear	12.7 ± 7.3	14.1 ± 10.3	12.6 ± 7.0	0.039
	Right ear	12.8 ± 8.5	14.3 ± 12.4	12.7 ± 8.1	0.047
	total	14.0 ± 7.3	15.3 ± 10.0	13.8 ± 6.9	0.084
NIHL BC Mean ± SD	left ear	7.5 ± 7.1	8.6 ± 10.1	7.4 ± 6.8	0.123
	Right ear	7.4 ± 7.9	8.5 ± 10.6	7.4 ± 7.6	0.038
	total	8.6 ± 6.8	9.7 ± 9.7	8.5 ± 6.5	0.179
Hearing loss >25 dB n (%)	Left ear AC	66 (2.9)	9 (5.1)	57 (2.7)	0.059*
	Right ear AC	82 (3.5)	12 (6.8)	70 (3.3)	0.019*
	Total AC	41 (1.8)	5 (2.8)	36 (1.7)	0.198*
	Left ear BC	38 (1.6)	6 (3.4)	32 (1.5)	0.064*
	Right ear BC	41 (1.8)	5 (2.8)	36 (1.7)	0.198*
	Total BC	20 (0.9)	3 (1.7)	17 (0.8)	0.191*

NIHL: Noise Induced Hearing Loss, AC: Air conduction, BC: Bone conduction, * Fisher's Exact Test

Table 3. High frequency (occupational frequencies) hearing loss of study participants and comparison of white-collar and blue-collar groups.

		Total n=2312	White Collar n=176	Blue Collar n=2136	P-value
NIHL AC Mean ± SD	left ear	23.1 ± 13.5	25.9 ± 17.5	22.9 ± 13.0	0.192
	Right ear	23.0 ± 14.1	24.9 ± 18.7	22.9 ± 13.6	0.932
	Total	21.5 ± 11.2	22.7 ± 14.3	21.4 ± 10.9	0.735
NIHL BC Mean ± SD	left ear	20.5 ± 13.3	23.2 ± 17.5	20.3 ± 12.9	0.233
	Right ear	20.3 ± 13.8	21.9 ± 18.1	20.2 ± 13.4	0.960
	Total	18.9 ± 11.0	19.9 ± 13.6	18.8 ± 10.8	0.916
Hearing loss >25 dB n (%)	Left ear AC	589 (25.5)	57 (32.4)	532 (24.9)	0.020*
	Right ear AC	564 (24.4)	44 (25.0)	520 (24.3)	0.454*
	Total AC	374 (16.2)	30 (17.0)	344 (16.1)	0.406*
	Left ear BC	477 (20.6)	52 (29.5)	425 (19.9)	0.002*
	Right ear BC	459 (19.9)	35 (19.9)	424 (19.9)	0.528*
	Total BC	311 (13.5)	25 (14.2)	286 (13.4)	0.416*

NIHL: Noise Induced Hearing Loss, AC: Air conduction, BC: Bone conduction, * Fisher's Exact Test workers are routinely exposed to elevated noise levels. Previous studies have identified age, sex, duration and intensity of noise exposure (LAeq), and concomitant risk factors such as smoking or exposure to ototoxic agents as influential determinants of hearing loss [19–22]. The present study aimed to evaluate the hearing status of employees in a major automobile manufacturing company and to compare audiometric outcomes between noise-exposed blue-collar workers and non-exposed white-collar administrative staff.

The demographic profile of participants revealed a mean age of 42.9 years, with white-collar workers being, on average, two years older than blue-collar workers. This modest age difference is likely attributable to differences in educational requirements, delayed employment, and later retirement age among white-collar employees. Given the relatively narrow age gap and the participants' age distribution predominantly under 50 years, the influence of age-related hearing loss was considered minimal in interpreting group differences.

Audiometric assessment, including both air and bone conduction thresholds across both ears, indicated no clinically or statistically significant differences in overall hearing thresholds between groups. The prevalence of hearing loss exceeding 25 dB HL remained below 10% across all subgroups. These findings are consistent with previous epidemiological studies suggesting that not all industrial noise exposure leads to measurable hearing impairment, particularly when effective hearing conservation programs are in place [23, 30, 31].

Interestingly, contrary to expectations, low-frequency hearing thresholds were slightly worse among white-collar workers. Statistically significant differences were observed in air conduction thresholds for both ears and bone conduction thresholds in the right ear, although the mean differences were less than 2 dB and therefore not clinically meaningful. Notably, the prevalence of low-frequency air conduction hearing loss (>25 dB HL) in the right ear was significantly higher in white-collar workers, a finding that may point to non-occupational contributors.

Several hypotheses can be proposed to explain this counterintuitive pattern. One plausible explanation relates to the Healthy Worker Effect, a well-established phenomenon in occupational epidemiology. Blue-collar workers, due to the inherent risks of industrial noise exposure, are subjected to rigorous pre-employment medical screenings, including detailed audiometric assessments. Only candidates with excellent baseline hearing are hired, and these individuals are subsequently enrolled in structured hearing conservation programs from the start of their employment. In contrast, white-collar employees, typically hired at older ages and often exempt from strict pre-employment auditory screening, may not benefit from early or continuous hearing health surveillance, making them more vulnerable to age-related or lifestyle-related hearing loss [32].

This pattern was also evident in the assessment of high-frequency hearing thresholds. Although mean hearing levels did not differ significantly, the prevalence of hearing loss >25 dB HL in the left ear—both in air and bone conduction—was significantly higher among white-collar employees. Given that high frequencies are more susceptible to occupational noise damage, these findings further support the hypothesis that systematic occupational health interventions among blue-collar workers may mitigate the expected detrimental effects of noise exposure.

The divergence in findings between the present study and those reported in other regions is noteworthy. For example, studies have reported prevalence rates ranging from 2.9% to nearly 50% among industrial workers, influenced by variations in noise levels, enforcement of regulations, access to protective equipment, and methodological differences [24–28]. In a Norwegian cohort, Molaug et al. reported that long-term occupational noise exposure was significantly associated with a gradual decline in hearing thresholds over 20 years, even at moderate exposure levels. These findings highlight the importance of early identification and consistent monitoring of hearing status in noise-exposed populations, supporting the effectiveness of preventive strategies such as regular hearing assessments and exposure reduction programs [33]. In contrast, de Rezende et al. analyzed a decade of occupational hearing loss notifications and found persistently high rates of noise-induced hearing loss across various job categories, including vehicle assembly. The data suggested limited effectiveness of hearing conservation programs, with notable asymmetry in hearing loss patterns—particularly affecting the left ear—highlighting potential regional disparities in preventive measure implementation [34]. Similarly, a study in Canada by Neitzel et al. emphasized that consistent personal protective equipment (PPE) use and job rotation significantly reduce NIHL prevalence in similar noise ranges [35].

It is also worth noting that in many high-income countries, improvements in industrial hygiene and widespread adoption of hearing conservation protocols have led to a documented decline in NIHL, with age now emerging as the dominant determinant of hearing decline in the working population [29, 36].

Cultural and national contextual factors may also play a role. In Iran, universal conscription exposes all men to potential noise hazards during military service, regardless of occupation. A study from South Korea—where a similar system is in place—highlighted the long-term impact of military noise exposure on men's auditory health [24]. Thus, a portion of the observed hearing deficits, particularly among white-collar staff, may have originated outside the workplace.

Collectively, these findings underscore that occupational noise exposure is not the sole determinant of hearing loss among industrial workers. Instead, a complex interplay of selection processes, demographic factors, and occupational health system rigor shapes the hearing health outcomes of workers.

This study is limited by its cross-sectional design, which precludes causal inference. Additionally, the absence of baseline audiometric data limits our ability to determine temporal changes. Future longitudinal studies incorporating detailed military and recreational noise histories, as well as female participants, are recommended to extend generalizability and explore gender-related vulnerabilities.

CONCLUSION

In conclusion, the findings of this study challenge the traditional assumption that occupational noise exposure is the primary driver of hearing loss among industrial workers. Despite prolonged exposure to industrial noise, blue-collar workers demonstrated comparable—or even better—hearing outcomes than their white-collar counterparts. This paradox may be attributed to the effective implementation of structured occupational health and hearing conservation programs for noise-exposed employees, alongside rigorous pre-employment screening.

These results highlight two critical considerations: first, that noise exposure alone cannot reliably predict hearing loss prevalence in industrial settings; and second, that occupational group comparisons must account for the Healthy Worker Effect and other confounding factors, such as non-occupational exposures and disparities in health surveillance coverage. Continued investment in comprehensive, evidence-based hearing conservation strategies remains essential for preserving auditory health across all workforce segments.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this study.

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AUTHOR CONTRIBUTION

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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