FLUORIDE

Quarterly Journal of The International Society for Fluoride Research Inc.

# Exploring the Link Between Fluoride Consumption and Vocal Health in Professional Singers: Focus on Opera Artists

Unique digital address (Digital object identifier [DOI] equivalent):
https://www.fluorideresearch.online/epub/files/311.pdf

Weina Chu[1, 2], Peng Yan[3], Mehboob Ul Hassan[4], Sahib Alam[5,*]

1. Department of Arts, Hefei Preschool Education College, Hefei, Anhui, 230011 China.
2. Department of Music Sahmyook University, Seoul, 01795, South Korea.
3. Department of Interdisciplinary Arts, Sahmyook University, Seoul, 01795, South Korea.
4. Islamic Banking Center, Department of Economics, College of Business Administration, King Saud University, Riyadh, Kingdom of Saudi Arabia.
5. Department of Agricultural Chemistry and Biochemistry, the University of Agriculture Peshawar, 25130, Pakistan.

***Corresponding author:**
Dr. Sahib Alam
Department of Agricultural Chemistry and Biochemistry
The University of Agriculture
Peshawar, 25139, Pakistan
Phone: (+92) 3339386835
E-mail: dralam@aup.edu.pk

Accepted: 2024 Dec 20 20.
Published as e311: 2024 Dec 22.

## ABSTRACT

**Purpose:** This study aimed to investigate the effects of fluoride exposure and vocal usage frequency on vocal health outcome variables, perceived vocal quality and vocal range reduction, informed by the mediated variable perceived laryngeal discomfort. The theoretical framework of this research is based on Health Belief Model (HBM), applied to professional opera singers in China.

**Methods:** Based on an online survey from 200 professional opera singers in China, data was collected. Phonetic laryngeal structural equation modeling (SEM) was used to examine relationships between fluoride exposure, vocal usage frequency, perceived laryngeal discomfort and health outcomes. Reliability and validity of the constructs were confirmed using confirmatory factor analysis (CFA).

**Results:** The results suggest that perceived laryngeal discomfort mediates the effects of both fluoride exposure and vocal usage frequency on perceived vocal quality and vocal range reduction. Its importance to understanding how environmental and behavioral factors affect vocal health is demonstrated by the role of perceived laryngeal discomfort as a critical mediating variable. The results highlight the need for interventions to prevent fluoride exposure and laryngeal discomfort to maintain vocal health in professional singers. Vocal health programs should incorporate strategies to reduce environmental risks and manage vocal strain. In addition, the application of the HBM is expanded to include laryngeal discomfort as a key mediator between environmental and behavioral factors and vocal health.

**Conclusion:** The study links fluoride exposure, laryngeal discomfort, and vocal health, emphasizing the need to address environmental and behavioral risks. It highlights long-term impacts on occupational voice users, calls for further research, and proposes targeted strategies to safeguard vocal quality for professionals like singers and teachers.

***Key-Words:*** *Fluoride, vocal health; Opera singer; Laryngeal discomfort; Health belief model*

## INTRODUCTION

Fluoride is well known as a strong promoter of dental health as it is included in drinking water and diet and dental hygiene products. Although the beneficial role of fluoride in preventing dental caries is well-established, recent concerns have been raised about its potential adverse effects on other aspects of health. This is particularly important for professional singers, especially opera singers, as there are concerns about the potential impact of fluoride on vocal health. Opera singers rely heavily on their vocal performance (Figure 1) which is central to both their professional success and personal fulfillment [1]. The relationship between fluoride exposure and vocal health is critical, and yet there is a large research gap on fluoride exposure and professional singers, whose vocal demands are particularly intense, which is partly due to a lack of knowledge about the mechanisms by which fluoride exposure impairs vocal health [2].

Figure 1: Opera-Shows in different regions of the China

All professional singers (and most singers in general) often have similar challenges with vocal fatigue, dryness, and throat irritation that can decrease their potential to perform at optimal levels. Challenges often attributed to high levels of vocal usage, environmental factors and individual susceptibility to vocal strain, are experienced with these unit. Although fluoride exposure can help prevent dental decay, excess amounts have been blamed for certain health allegations [3]. For instance, many people in China (with considerable differences in fluoride levels in drinking water in different areas) have been exposed to inadequately or excessively polluted fluoride and to dental, skeletal fluorosis. Given this context therefore, fluoride exposure should be studied to ascertain whether it worsens vocal discomfort and if further long-term effects such as vocal range reduction, or decreased vocal quality occur. This prompts a crucial question about how fluoride exposure impacts vocal health and the mechanisms through which it exerts this influence.

Excess fluoride in drinking water can have serious health effects, with the thyroid gland and vocal cords being particularly vulnerable. The condition of skeletal and dental fluorosis happens mainly in teeth and bones, though chronic exposure can provoke fluorosis. But fluoride can also cause dysfunction of the endocrine system, most notably of the thyroid gland, which regulates metabolism and the level of hormones in the body. Such disruption may cause hypothyroidism, with symptoms ranging from a hoarse voice to throat swelling to vocal cord thickening. Prolonged fluoride exposure could also change laryngeal muscles causing hoarseness or altered voice quality. In very rare cases, skeletal fluorosis can lead to bone deformities in jaw and neck bones (including voice and speech mechanics) and can cause deformities in the bones.

Excessive fluoride is more directly related to the thyroid and vocal cords for singers. As the thyroid is so important for vocal health, and Hypothyroidism (due to fluoride induced thyroid dysfunction) can give a deep, hoarse, voice and inability to control pitch. It can have far reaching effect on a singer because hypothyroidism can impact a singer's vocal resonance and flexibility. Moreover, although there is not as much to be known

about these direct effects of fluoride on the vocal cords, excess fluoride may cause inflammation or a change in structure of the larynx presenting as hoarseness, vocal fatigue, or performance related issues. Extremes of skeletal fluorosis may result in jaw or neck deformities that may disrupt the mechanics of vocalization and thereby negatively impact a singer's ability to effectively use the vocal instrument.

Fluoride exposure may influence vocal health indirectly through factors like perceived laryngeal discomfort, a condition common among professional singers characterized by throat irritation, dryness, and vocal strain, which can lead to compensatory vocal behaviors [4]. Fluoride's known effects on mucosal membranes may contribute to these symptoms, potentially mediating the relationship between fluoride exposure and vocal outcomes. Additionally, excessive fluoride intake is linked to thyroid dysfunction, such as hypothyroidism, which can cause a deeper, hoarse voice, reduced pitch control, and impaired vocal resonance and flexibility, significantly affecting singers [5]. While direct effects of fluoride on the vocal cords remain less understood, it may cause inflammation or structural changes in the larynx, leading to hoarseness, vocal fatigue, and performance issues [6]. Severe skeletal fluorosis could further disrupt vocal mechanics through jaw or neck deformities, compromising a singer's ability to effectively use their voice.

This research addresses a critical gap in understanding the impact of fluoride exposure on vocal health, particularly for professional opera singers who face intense vocal demands. By highlighting the disproportionate risks to singers' vocal performance and advocating for proactive fluoride mitigation measures, the study offers valuable guidance for voice protection. Beyond opera singers, the findings have broader implications for individuals in voice-dependent professions, such as teachers, public speakers, and contact center employees (Figure 2), especially in regions like Pakistan with naturally high fluoride levels in water. Additionally, the research enriches existing literature by exploring the underexamined area of fluoride's effects on mucosal health and laryngeal function, emphasizing the mediating role of perceived laryngeal discomfort. This nuanced approach not only sheds light on the mechanisms linking fluoride exposure to vocal health but also underscores the importance of addressing laryngeal discomfort in vocal health management strategies.

Figure 2: A famous opera singer in a music show

During the current study, the fluoride exposure perceived laryngeal discomfort, and vocal health outcome were measured in a sample of professional opera singers using a cross-sectional survey design. A composite score for fluoride exposure was based on self-reported drinking water, diet and oral hygiene products intake. The perception of laryngeal discomfort was determined by means of a validated scale-such as Vocal Fatigue Index (VFI), that assesses voice fatigue symptoms (throat irritation and dryness) and vocal strain. Vocal health outcomes were measured using two key indicators: and vocal quality, via tools such as the Singer's Voice Handicap Index (SVHI), reported by the musician themselves.

Thus, the aim of the present study was to explore the relationship between fluoride exposure and vocal health in professional opera singers, focusing on two key outcomes: reduction in vocal range and quality. It investigates whether perceived laryngeal discomfort mediates this relationship, addressing the research question of how fluoride exposure impacts vocal performance through this mechanism. By examining these links, the study seeks to provide insights into the broader effects of environmental exposures on vocal health, offering practical implications for controlling fluoride levels and managing vocal discomfort in professional singers. The findings are expected to enrich research on vocal health by emphasizing the role of mediating factors in understanding health outcomes.

### 1.1 Health Belief Model

The Health Belief Model (HBM) is a widely recognized framework that explains health behavior based on individuals' beliefs about the severity of a health risk and the benefits of taking preventive action [7]. Initially developed to understand inconsistent use of preventive measures like vaccinations, the HBM has since been adapted to various health contexts, including vocal health. It suggests that decisions to act are influenced by perceived susceptibility to a health problem, the seriousness of its consequences, the benefits of action, and barriers to implementation [8].

This study applies the HBM to explore how professional opera singers, whose vocal health is critical due to their intensive vocal demands, perceive and respond to risks like fluoride exposure. Singers with heightened perceptions of susceptibility and severity regarding fluoride's effects on vocal range and quality are more likely to adopt preventive measures, such as moderating fluoride intake or seeking interventions to reduce discomfort. Conversely, those with lower perceived risk or limited access to resources may neglect protective actions. By integrating cognitive and behavioral factors, the HBM offers valuable insights into how beliefs shape vocal health behaviors. This framework highlights the need for targeted strategies to mitigate risks and promote vocal health care among high-risk populations like opera singers.

### 1.2 HBM is applied in Vocal Health and Fluoride Exposure

In a wide range of studies, the HBM has been used to answer questions of how human beings behave in response to defined health threats. Numerous studies have used it to examine the adoption of smoking cessation programs [9], vaccination behaviors [10] as well as changes in dietary behaviors in populations at risk for chronic diseases [11]. In this study, the HBM is adapted to address a unique and understudied context: an exploration of the relationship of opera singer fluoride exposure, laryngeal discomfort perception, and vocal health. Fluoride is of immense inquiry with respect to dental health, but not as much regarding vocal health specifically in the context of populations having higher vocal demands.

For instance, in China, from different geographical regions different amount of fluoride exposure exists due to variations in fluoride level in drinking water. In view of these facts, excess fluoride exposure has been linked to adverse effects such as dental and skeletal fluorosis, the increased likelihood that fluoride will irritate the mucous membrane in the alimentary canal [12] while too little fluoride is known to contribute to poor dental health. Fluoride related laryngeal discomfort may pose a greater threat to the vocal health and performance of professional singers in such regions. The HBM is useful for developing a framework in which to study how these local people perceive fluoride exposure risk and how they respond to it in their setting.

### 1.3 Overview of the components of the HBM and its application to the study

This study focuses on the key components of the HBM such as perceived susceptibility, severity, barriers and cues to action to investigate how beliefs about fluoride exposure influence vocal health behaviors. Perceived susceptibility to fluoride-related laryngeal discomfort may vary among opera singers, with those consuming high levels of fluoride or experiencing preexisting vocal issues perceiving themselves at greater risk and thus more likely to take preventive measures. Perceived severity plays a significant role in shaping attitudes and behaviors, as singers who believe fluoride exposure could severely impact their vocal health—such as causing a reduction in vocal range or quality—are more motivated to reduce exposure. However, perceived barriers, such as limited knowledge about fluoride or lack of access to fluoride-free alternatives, may hinder preventive actions, highlighting the need for targeted interventions to address these challenges. Cues to action, such as external prompts from vocal health workshops, advice from coaches, or persistent laryngeal discomfort, can motivate singers to reevaluate their fluoride intake and adopt protective behaviors. For instance, singers experiencing persistent throat irritation may become more aware of the potential impact of fluoride and take steps to mitigate its effects. Together, these components of the Health Belief Model help explain how opera singers perceive and respond to fluoride-related vocal health risks, providing a foundation for promoting behavior change and protecting vocal health.

### 1.4 Implications from the HBM of Vocal Health Interventions

This study applied the HBM in order to ascertain the cognitive, and behavioral factors which help determine a professional singer's decision to mitigate exposure to fluoride and laryngeal discomfort. The findings can help lead to the development of targeted interventions for helping singers maintain vocal health. For instance, while educating opera singers about fluoride's potential effects on vocal health may lead to more awareness of fluoride and its potential threats to vocal health, certainly as a spur to action, campaigns to opera singers could also focus on making opera singers aware of fluoride's protection mechanisms as well as the benefits of protective behaviors and on reducing barriers to action.

Moreover, the HBM underlines the relevance of the adaptation of interventions to the particular needs and contexts of various populations. Interventions for singers of China, where fluoride exposure is highly variable, could include region specific information about fluoride exposure, offers of water or other alternatives to products containing fluoridated treatments. This study helps fill a gap of understanding by providing a deeper understanding into how fluoride exposure affects vocal health while also providing a basis to develop effective preventive measures for opera singers, who face unique challenges related to fluoride exposure.

## THEORITICAL BACKGROUND

The Health Belief Model (HBM), introduced by Rosenstock in 1974 [13], explores how perceptions of risk and benefits influence health behaviors. This study applies the model's key constructs i.e., susceptibility, severity, barriers, and cues to action to examine how fluoride exposure impacts professional opera singers' vocal health and performance experiences.

This study explores how opera singers' perceptions of susceptibility, severity, and barriers influence their responses to fluoride exposure, particularly regarding vocal health. Perceived susceptibility reflects individuals' belief in their vulnerability to a health threat. For opera singers, those experiencing laryngeal discomfort may associate fluoride exposure particularly during puberty with heightened risk, prompting them to adopt protective measures such as avoiding fluoride-containing products or altering oral health routines. Champion and Skinner [8] showed that perceived susceptibility can lead individuals to take action, and in contexts where controls over risk are closely linked to their professional or personal wellbeing [14].

Perceived severity is the second concern that refers to the extent to which individuals believe the consequences of a health threat will significantly impact them. Professional singers often worry that fluoride exposure could diminish vocal quality or range, undermining their careers and artistic expression. These fears align with findings by Norman et al. [9], which emphasize perceived severity as a critical

motivator for health behavior change, especially when livelihoods are at stake.

Likewise, perceived barriers represent obstacles that hinder protective behaviors. Barriers like limited awareness of fluoride's impact on vocal health, scarcity of fluoride-free products, or misinformation can prevent singers from adopting preventive measures, despite recognizing potential risks. The findings of Glanz et al. [11] highlight the role of barriers as major deterrents to behavior change. Addressing these barriers through education and access to fluoride-free products could encourage preventive actions among singers, ensuring their vocal health and professional longevity.

Figure 3: Opera singer participating in the concert

Motivation to perform preventative measures is driven by external or internal cues to act. Perceived laryngeal discomfort, or throat irritation, dryness, vocal fatigue and the like, is measured as cues to action in this study. These symptoms are acting as triggers that get singers to reevaluate their fluoride intake, or vocal health practices. Singers may also adopt preventive measures in response to external cues: such as recommendations from vocal coaches, or participation in vocal health workshops. Many become powerful motivators for behavior change because internal cues, such as persistent laryngeal discomfort, exist. As Hunter et al. [15] found, laryngeal discomfort is a key driving intervention of vocal health among professional singers. Like Smith et al. [16] persistent throat discomfort in teachers indicated that teachers may initiate health behavior change based on external and internal cues. The framework of the study presented in the Figure 4.

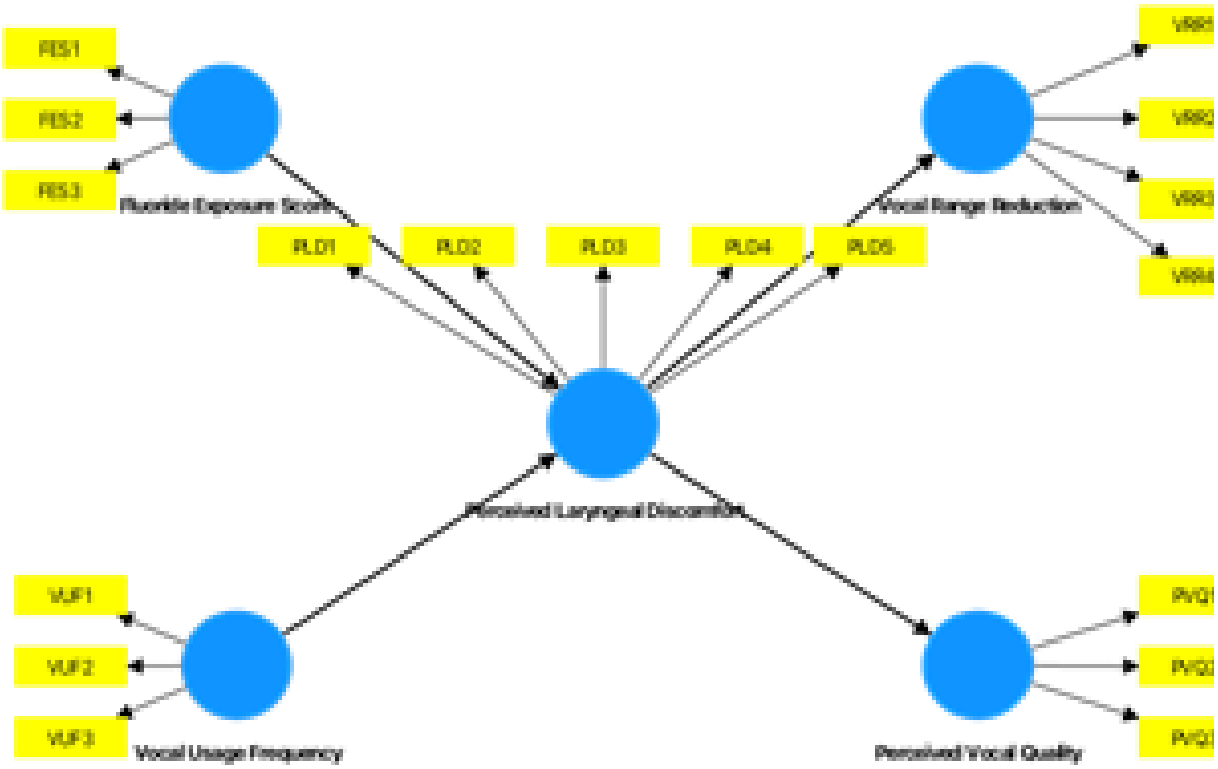


Figure 4: Framework of the study

In this study, the application of the HBM supplies a comprehensive framework for understanding how professional singers view and respond to fluoride related exposures. It describes relationships between perceived susceptibility, severity, barriers, and cues to action, cognitive and behavioral factors that influence vocal health outcomes.

The results fit with much of the existing research showing that people's perceptions of their health were instrumental in how they behaved. Examples are given by Glanz et al. [11] and Champion and Skinner [8] on how the cognitive factors are to be addressed to promote behavior change for positive health outcomes.

Table 1: Summary of Studies Relevant to HBM Components in Vocal Health and Related Fields

| Reference | HBM Component | Sample Frame | Focused Area | Results |
|---|---|---|---|---|
| [7] | Perceived Susceptibility | General Population | Development of HBM Framework | Highlighted the importance of vulnerability perception in driving health behaviors. |
| [8] | Perceived Severity | Health Behaviors | HBM in Public Health | Demonstrated the role of severity beliefs in motivating preventive actions. |
| [9] | Perceived Susceptibility | Smokers | Smoking Cessation | Found that severity perceptions influenced smoking cessation behavior. |
| [11] | | Chronic Disease Patients | Dietary Behavior | Identified barriers as the most significant deterrent to adopting healthier behaviors. |
| [13] | Cues to Action | Professional Singers | Vocal Discomfort | Found that laryngeal discomfort significantly prompted singers to adopt protective behaviors. |
| [16] | Perceived Barriers | Teachers | Occupational Voice Disorders | Observed that persistent vocal discomfort triggered professional interventions. |
| [17] | Cues to Action | Call Center Employees | Environmental Factors and Vocal Health | Highlighted environmental contributors to vocal discomfort. |
| [18] | Perceived Severity | Opera Singers | Vocal Fatigue and Performance | Identified that vocal strain led to reduced vocal range and endurance among singers. |
| [19] | Perceived Barriers | Industrial Workers | Environmental Health Risks | Demonstrated that self-efficacy and barriers influenced the adoption of protective behaviors. |
| [20] | Perceived Barriers | Teachers and Performers | Voice Fatigue | Linked perceived environmental stressors to the development of vocal fatigue and discomfort. |

## HYPOTHESES

This study uses the Health Belief Model (HBM) as the theoretical framework through which fluoride exposure, frequency of vocal usage, perceived laryngeal discomfort, and their effect on vocal health outcomes are explored. Based on the constructs of the HBM, and previous literature, the following hypotheses are proposed to test these relationships and the mediating influence of laryngeal discomfort.

It was suggested that fluoride exposure directly affects perceived laryngeal discomfort. If you are a professional singer and are exposed to more fluoride through your drinking water, the food you eat or the things you use to clean your mouth, you may find that fluoride causes greater irritation and dryness in your larynx. Builds on prior research on environmental health risks related to fluoride demonstrating enhanced laryngeal discomfort and its potential for fluoro-induced mucosal tissue effects with the presumption of increased fluoride exposure. Thus, the following hypothesis is proposed:

***H1:*** *A strong positive relationship exists between Perceived Laryngeal Discomfort and Fluoride Exposure Score.*

Vocal health outcome variables are mediated by perceived laryngeal discomfort, which is a critical mediator of environmental and behavioral factors. Symptoms such as dryness, strain, and irritation in the larynx are expected to reduce singers' perceived vocal quality, due to discomfort in the larynx. Several prior studies have shown that laryngeal discomfort can generate a loss of confidence in ability to vocalize as well as hinder overall performance. Based on these findings, the second hypothesis is formulated as follows:

***H2:*** *A significant negative relationship is perceived Laryngeal Discomfort and Perceived Vocal Quality.*

Another vocal health outcome hypothesized to be associated with laryngeal discomfort is Vocal Range Reduction. If vocal flexibility is one of their strengths, professional singers rely on it, and discomfort in the larynx may hamper their ability to make or maintain higher and lower notes. Building on evidence from studies on vocal strain, this hypothesis posits the following:

**H3:** *A significant negative relationship exists between Vocal Range Reduction and Perceived Laryngeal Discomfort.*

Hypothesis II is also made that laryngeal discomfort is associated not only with the high use of the voice by singers but with how professional singers use their voices. Larynx stress is caused in large part by vocal usage frequency, represented by hours a day or week spent singing or performing professional vocal related activity. The prolonged strain is probably going to make wear and tear; in turn, affecting vocal health outcomes. Accordingly, the fourth hypothesis is proposed:

***H4:*** *Perceived Laryngeal Discomfort has a large positive relationship to Vocal Usage Frequency.*

The fifth hypothesis (H5a) suggests a mediated relationship in which perceived vocal quality is a function of perceived laryngeal discomfort, which in turn is mediated by fluoride exposure score. Increased laryngeal discomfort due to high fluoride exposure is expected to reduce vocal quality. This mediation hypothesis suggests that there is a middle step linking environmental exposure to vocal outcomes: discomfort. For professional singers, this pathway delineates the sheer extent of the cumulative effects of fluoride intake on that which goes awry in vocal performance in physical terms.

**H5a:** *Perceived Vocal Quality is negatively related to Fluoride Exposure Score, and partly through Perceived Laryngeal Discomfort.*

The mediation framework is extended in hypothesis 5a. The idea is that higher levels of fluoride make it uncomfortable, blocking singers from accessing their full range. In particular, discomfort is shown to mediate the influence of environmental factors on vocal capabilities, highlighting the importance of addressing underlying sources of discomfort in order to preserve vocal range in professional settings.

***H5b***: *Perceived Laryngeal Discomfort positively mediates a negative, indirect relationship between Fluoride Exposure Score and Vocal Range Reduction.*

***H6a:*** Perceived Laryngeal Discomfort partially mediates the indirect relationship between Vocal Usage Frequency and Perceived Vocal Quality.

According to the sixth hypothesis (H6a), perceived vocal quality is also indirectly influenced by vocal usage frequency in that perceived vocal quality is mediated by perceived laryngeal discomfort. The greater discomfort singers with high vocal usage frequency will experience, the lower their quality will be. Here, a mediated relationship between what vocal use is like and the physical toll of frequently vocal use is reflected in this tension between how uncomfortable vocal use can be and the importance of discomfort to link behavioral factors to vocal performance outcomes.

***H6b:*** Indirect negative relationship of Vocal Usage Frequency with Vocal Range Reduction is mediated by Perceived Laryngeal Discomfort.

Based on hypothesis 6b, the mediation model is extended to vocal range reduction and the relationship between vocal usage frequency and range limitation is speculated to be mediated by perceived laryngeal discomfort. Although not new, the understanding of the detrimental effects of high frequency vocal use in connection with discomfort is still not widely spread among professional musicians. The main thrust of this pathway is perceived cumulative effects of intensive vocal use on perceived physical sensations in the larynx

with ensuing effects on vocal performance. The mediated relation defines the importance of laryngeal discomfort between the behavioral and voice health variables.

## MATERIAL AND METHODS

### *Data Collection and sampling plan*

The data for this research was gathered using a web-based survey instrument via Qualtrics. The survey participants were professional opera singers who were all residents of China. Drinking water fluoride levels vary geographically in such a way in China that it presents with a unique opportunity to investigate the potential effect of fluoride exposure on vocal health. Participants were solicited from professional networks, opera groups, vocal training programs and forums dedicated to singers.

We invited participants randomly by email and on messaging platforms to get a broad representation of the target population. All responses were collected in a coded format in order to maintain anonymity and confidentiality, and not include any personal identifiers in the dataset. The survey was completely voluntary; subjects could opt out of participation without any penalty.

The study participants need to be above 18 years of age, professional opera singers and have at least three years of experience in the domain. This ensured that before any analyses were done, the sample included individuals with significant vocal demands and potential exposure to the factors under study. In order to capture variability in fluoride exposure and correlate its impact on vocal health, we included urban and rural singers.

### *Sample Size*

Determination of sample size for this study was done through GPower 3 statistical software. Using an F test, fixed model, a linear multiple regression and deviation of $R^2$ from zero, I performed a minimum sample size calculation. Using an alpha or type 1 error at 0.05, power of 0.95 and medium effect size ($f^2 = 0.3$), the minimum sample size needed was 65 participants.

To achieve robustness, and accommodate incomplete responses, the survey was administered to 500 professional opera singers in China across several regions with different fluoride levels. 2,000 valid responses remained after removal of incomplete responses and invalid entries, above the minimum requirement and allowing statistical power.

### Measures

Included in the survey were validated scales and items to measure the study variables. The constructs and their operationalization are described below:

Fluoride Exposure Score: In a survey that quantified exposure to fluoride from water, diet and oral hygiene habits. Exposure on a Likert scale (1 = minimal exposure, 5 = high exposure) was rated by respondents. With China's water fluoridation varying geographically, this measure controlled for geographic variation in cumulative fluoride intake among singers in different geographic locations. Fluoride exposure was measured adopted from Xu et al. [21].

Vocal Usage Frequency: The self-reported average number of hours per day or week spent singing or the voice for professional purposes. The estimates were made by participants and grouped by frequency band for analysis. The measures were taken according to Hunter et al. [15].

Perceived Laryngeal Discomfort (Mediating Variable): The progression was measured using the Vocal Fatigue Index (VFI), a validated scale previously used to assess symptoms like throat irritation, dryness and vocal strain. The degree of the persons discomfort was rated using a Likert scale (1 = no discomfort, 5= severe discomfort). This variable acted as a mediator between fluoride exposure and vocal usage and vocal health outcomes. The measure items adopted from O'Connell Ferster and Hu [22].

Perceived Vocal Quality (Dependent Variable): Singer's Voice Handicap Index (SVHI), which is a validated instrument used to measure singers' perception of their vocal quality and performance difficulties is evaluated. The level of vocal performance was rated on a Likert scale (1 = excellent vocal quality, 5 = very poor vocal quality) for participant self-assessment. The items are taken from Kasama and Brasolotto [23].

Vocal Range Reduction (Dependent Variable): It is measured as a self-reported decrease in vocal range on a numerical scale (1=no reduction, 5 severe reduction).

There was a rated ability to sustain high and low notes for a given period of time [24].

***Data Analysis***

Structural Equation Modeling (SEM) was used to test the proposed hypotheses and to examine the relationships between fluoride exposure, vocal usage frequency, perceived laryngeal discomfort and vocal health outcomes. We applied the bootstrapping method of mediation analysis to determine indirect effects stemming from the perceived laryngeal discomfort. All measures were conducted on descriptive statistics and reliability for internal consistency and validity.

***Ethical Considerations***

This study was undertaken with ethical approval from a university based institutional review board. The survey was completed by all participants who gave informed consent and that their anonymity and confidentiality of responses were assured. The data was collected securely and used only for research purposes. It is a testament of cultural sensitivity and data privacy practices like that observed in China and indeed, special attention was paid to compliance with local regulations.

The use of this methodology allows for the development of a robust foundation for study of the effect of fluoride exposure and vocal usage frequency and the established perception of laryngeal discomfort on vocal health outcomes within a Chinese context through which environmental and behavioral factors play a role in the development of vocal performance.

## RESULTS

This study was conducted using SPSS version 26 and SmartPLS 4.0.3 for statistical analyzes. Descriptive statistics were calculated to summarize the demographic characteristics in the sample and if it is representative. To validate the measurement model, we then performed confirmatory factor analysis (CFA) and structural equation modeling (SEM) to test the hypothesized relationships. Descriptive statistics are presented as first stage, and then analyses on reliability, validity, and model fitness are presented as the second stage.

***Descriptive Statistics***

Demographic data of the participants were collected for sampling characteristics and eligibility criteria of the study. Professional opera singers from China were the participants; fluoride exposure variability and vocal health outcomes were of particular emphasis. The demographic distribution of the sample, consisting of gender, age and professional experience, is presented in Table 2.

***Common Method Bias***

Harman's single factor test was conducted to evaluate a common method bias amongst these variables. The total variance explained by the factor was calculated on all items of the survey loaded on a single factor. The results, presented in table 3, indicate that single factor accounted for 27.95 percent of total variance, while this is consistently far LESS than the recommendation for a factor accounting for more than 50 percent of the variance [25]. This evidence suggests that the common method bias in this study was not a problem.

***Confirmatory Factor Analysis (CFA)***

The measurement model, including item validity, reliability, and ability to differentiate latent variable items was confirmed through confirmatory factor analysis (CFA). The factor loadings, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE), for each construct are given in table 4. The results confirm that all constructs meet the recommended thresholds: Cronbach's alpha>0.7, CR > 0.7 and AVE > 0.5 [26]. The graphical representation of the study CFA presented below in Figure 5a-c.

**Table 2:** Descriptive Statistics of Respondents

| Variable | Frequency | % | Valid (%) | Cumulative (%) |
|---|---|---|---|---|
| **Gender** | | | | |
| Male | 90 | 45 | 45 | 45 |
| Female | 110 | 55 | 55 | 100 |
| **Age (Years)** | | | | |
| 18–24 | 15 | 7.5 | 7.5 | 7.5 |
| 25–34 | 40 | 20 | 20 | 27.5 |
| 35–44 | 60 | 30 | 30 | 57.5 |
| 45–54 | 50 | 25 | 25 | 82.5 |
| 55–64 | 25 | 12.5 | 12.5 | 95 |
| 65–74 | 10 | 5 | 5 | 100 |
| **Professional Experience** | | | | |
| 3–5 years | 30 | 15 | 15 | 15 |
| 6–10 years | 50 | 25 | 25 | 40 |
| 10+ years | 120 | 60 | 60 | 100 |

**Table 3:** Results of Harman's Single-Factor Test

| Component | Initial Eigen values | % of Variance | Cumulative % |
|---|---|---|---|
| 1 | 11.18 | 27.95 | 27.95 |
| 2 | 3.865 | 9.662 | 37.612 |
| 3 | 3.012 | 7.529 | 45.141 |
| 4 | 2.454 | 6.134 | 51.276 |

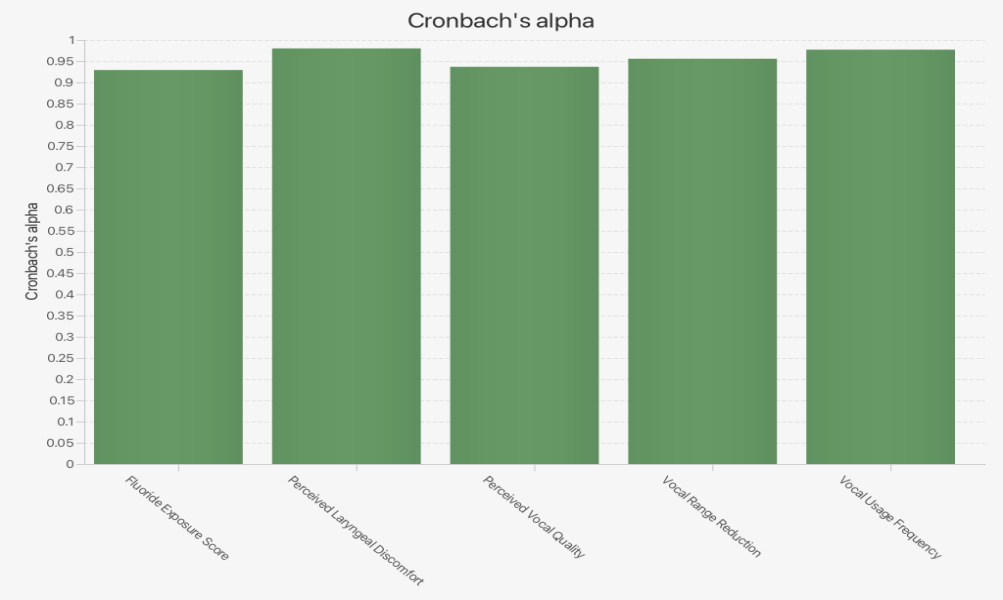


**Figure 5a**: Cronbach Aplha

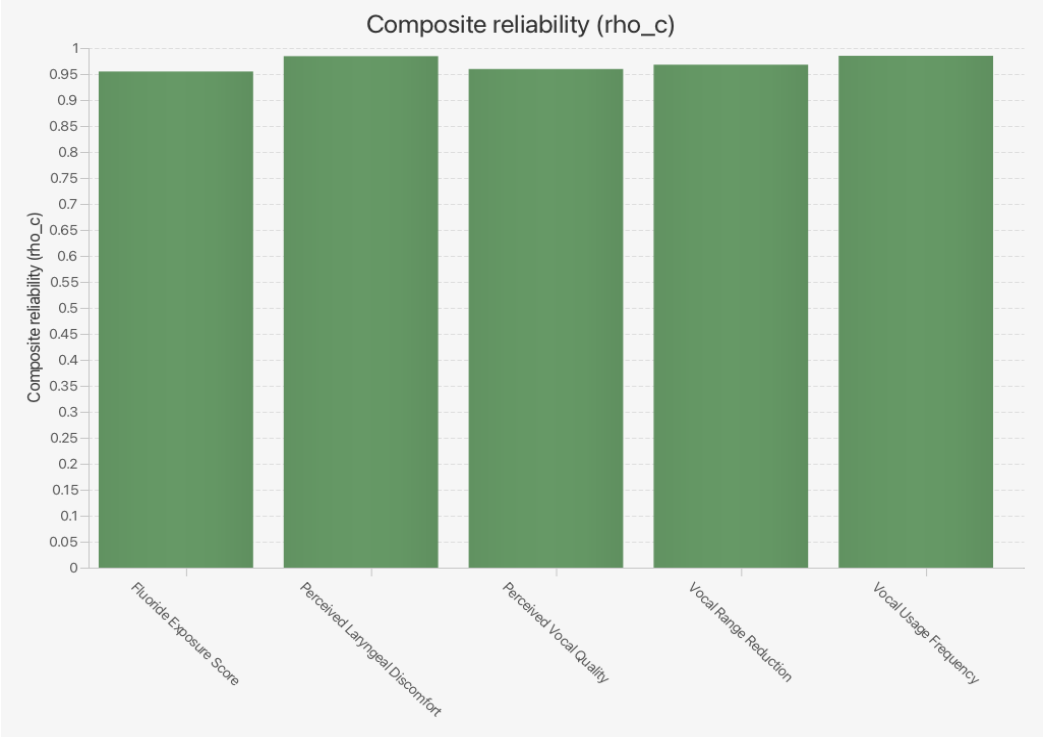


**Figure 5b:** Composite Reliability of the study

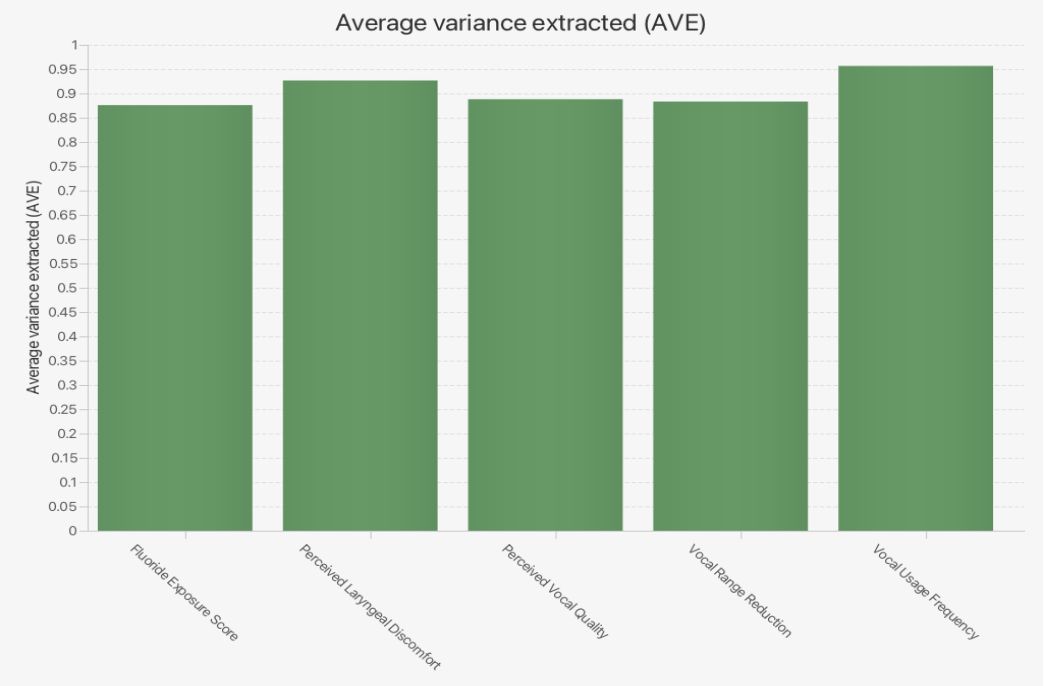


Figure 5c: AVE graphical representation of the study

**Table 4:** Factor loadings

| Constructs | Items | Loadings | Cronbach Aplha | CR | AVE |
|---|---|---|---|---|---|
| Fluoride Exposure Score | FES1 | 0.955 | 0.929 | 0.955 | 0.876 |
| | FES2 | 0.904 | | | |
| | FES3 | 0.948 | | | |
| Perceived Laryngeal Discomfort | PLD1 | 0.966 | 0.980 | 0.980 | 0.927 |
| | PLD2 | 0.974 | | | |
| | PLD3 | 0.946 | | | |
| | PLD4 | 0.964 | | | |
| | PLD5 | 0.962 | | | |
| Perceived Vocal Quality | PVQ1 | 0.962 | 0.937 | 0.960 | 0.888 |
| | PVQ2 | 0.944 | | | |
| | PVQ3 | 0.920 | | | |
| Vocal Range Reduction | VRR1 | 0.955 | 0.956 | 0.968 | 0.883 |
| | VRR2 | 0.947 | | | |
| | VRR3 | 0.912 | | | |
| | VRR4 | 0.945 | | | |
| Vocal Usage Frequency | VUF1 | 0.980 | 0.977 | 0.985 | 0.957 |
| | VUF2 | 0.977 | | | |
| | VUF3 | 0.977 | | | |

**Table 5:** Fornell-Larcker criterion

| | FES | PLD | PVQ | VRD | VUF |
|---|---|---|---|---|---|
| **FES** | 0.936 | | | | |
| **PLD** | 0.227 | 0.963 | | | |
| **PVQ** | 0.479 | 0.475 | 0.942 | | |
| **VRD** | 0.419 | 0.453 | 0.614 | 0.940 | |
| **VUF** | 0.471 | 0.280 | 0.539 | 0.412 | 0.978 |

**Table 6:** Heterotrait-monotrait ratio (HTMT) – Matrix

| | FES | PLD | PVQ | VRD | VUF |
|---|---|---|---|---|---|
| **FES** | | | | | |
| **PLD** | 0.237 | | | | |
| **PVQ** | 0.516 | 0.495 | | | |
| **VRD** | 0.445 | 0.467 | 0.649 | | |
| **VUF** | 0.496 | 0.285 | 0.563 | 0.427 | |

***Discriminant Validity***

Using the Fornell-Larcker criterion, discriminant validity was shown. The square root of the AVE for each of the constructs is presented in Table 5 and is above their correlations with other constructs, thus demonstrating the discriminant validity. Furthermore, HTMT values (Table 6) were all below the recommended threshold (0.85) of discriminant validity of the constructs. The detail

measurement model is presented in figure 6. This section establishes the reliability and validity of the constructs, ensuring that the measurement model is robust and suitable for further structural equation modeling (SEM) analysis.

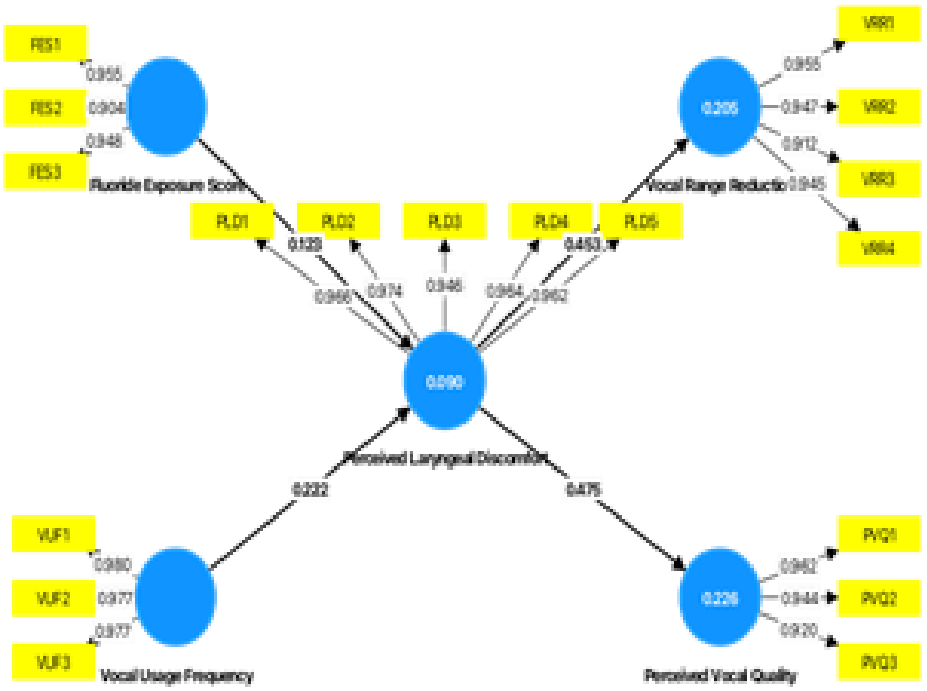


**Figure 6:** Measurement model of the study

***Structural model of the study***

The study conducted and proposed hypotheses were tested, and a structural model was developed to determine the relationships of the constructs under study. This analysis also verified that the structural model is in its theoretical terms extradited from the Health Belief Model (HBM) and supported statistically. The fit indices of the structural model indicated that the data was met with minimum acceptable criteria since values for CMIN, CFI, RMSEA and PCLOSE fell within acceptable ranges [27].

The relationships among the constructs and the hypotheses presented in this study are tested using the structural model. The structural model is based on the theoretical foundation of the Health Belief Model (HBM) assessing the effects fluoride exposure and vocal usage frequency have on perceived laryngeal discomfort, leading to vocal health outcomes. The hypothesized relationships are confirmed, and the strong evidence for the validity of the model is clear from the statistical results.

H1 examines this relationship between fluoride exposure score and perceived laryngeal discomfort. The results indicate that there is a strong positive relation ($\beta = 0.123$; $p < 0.001$) between laryngeal discomfort and higher fluoride exposure in professional opera singers. That finding indicates environmental factors (like fluorides consumption) are critical to vocal health. The analysis shows a strong positive relationship between perceived laryngeal discomfort and perceived vocal quality ($\beta = 0.475$, $p < 0.001$), for

H2. This result suggests that as laryngeal discomfort increases, singers perceive a great decrease in their vocal quality. Relevant to H3, perceived laryngeal discomfort also has a very large positive effect on vocal range reduction (β = 0.453, p < 0.001). This means that singers become less able to maintain a full vocal range because it increases discomfort.

Additionally, we find that there is a significant relationship (p < 0.001) with our fourth hypothesis, which is the combination between the perceived laryngeal discomfort and the vocal usage frequency (path coefficient is 0.222). The finding suggests that when vocal usage frequency is high there is greater pain reported with laryngeal discomfort, indicating that intense vocal activity has an impact on vocal health. Taken together, these results directly support the direct effects hypothesized by the model and show that environmental and behavioral factors determine the effect on vocal health.

Finally, the indirect effects of fluoride exposure and vocal usage frequency on vocal health outcomes are further explored through perceptions of laryngeal (throat) discomfort. Results for H5a show that laryngeal discomfort (β = 0.058, p < 0.001) mediates the relationship between fluoride exposure score and perceived vocal quality. Likewise, vocal range reduction is indirectly influenced by perceived laryngeal discomfort (β = 0.056, p < 0.001) mediated by fluoride exposure score for H5b. Confirmed are these findings that laryngeal discomfort serves as a key mediator in the relationship between fluoride exposure and vocal health outcomes.

In addition, the mediation analysis shows the existence of major indirect effects for vocal usage frequency. Indirectly vocal usage frequency affects perceived vocal quality through laryngeal discomfort for H6a (β = 0.106, p < 0.001). Vocal usage frequency indirectly affects vocal range reduction in H6b; laryngeal discomfort (β = 0.101, p < 0.001). These results support the important role of laryngeal discomfort in understanding the mediating pathways from environmental and behavior factors to vocal health.

Overall results show the hypothesized relationships are valid and have strong empirical support in the theoretical model. These findings point out the significant direct and mediated effects of perceived laryngeal discomfort in bringing together fluoride exposure and vocal usage frequency as mediators to vocal health outcomes. These findings suggest that these factors must be managed to counter their influence on vocal performance and may provide insight for preserving the vocal health of professional opera singers. The structural model is presented in Figure 7.


Figure 7: Structural model of the study

## DISCUSSION

As occupational voice users, professional opera singers are exposed to risks unique to environmental and behavioral factors which impact vocal health. In this study of perceived laryngeal discomfort as a mediating variable, relationships between fluoride exposure, vocal usage frequency, and vocal health outcome were investigated. The results offer important clues as to how environmental and occupational factors influence the singers' vocal performance and health.

Our results confirm the hypothesis of the effect of environmental fluoride causing throat irritation and dryness by providing positive support for the structural model that shows that fluoride exposure leads to increased perceived laryngeal discomfort [11]. In addition to the effects of fluoride, the study found that thyroid gland function was highly predictable from high-frequency vocal use, consistent with previous work on vocal fatigue and strain as a function of occupational voice use. The thyroid, which plays a crucial role in regulating metabolism and maintaining vocal cord health, can be affected by environmental factors, including fluoride exposure. Disruptions to thyroid function can lead to changes in voice quality, such as hoarseness or a weakened voice, further contributing to laryngeal discomfort. These results emphasize the simultaneous effect of external (fluoride exposure) and behavioral (vocal usage frequency) factors on singers' perceived discomfort [28].

Significant reduction of perceived vocal quality and vocal range was shown to depend on perceived laryngeal discomfort [29]. These findings support the major role of physical sensations in the larynx in predicting vocal performance outcomes. Vocal health is crucial for opera singing, as it directly reflects the condition and health of the laryngeal muscles and their innervation. This is in line with the current body of literature, which stresses the necessity of managing vocal strain and fatigue for professional voice users to maintain their performance level [5]. The mediation analysis also demonstrated the importance of perceived laryngeal discomfort as a pathway mediating fluoride exposure to vocal usage frequency to vocal health outcomes. We show that environmental and behavioral effects on vocal quality and range are

primarily mediated by their effects on vocalization and, to a lesser extent, on discomfort. This suggests a need for development of interventions that reduce laryngeal discomfort in order to improve vocal health outcomes. Results were discussed in relation to how environmental and behavioral variables interact to influence vocal health, which indicates a further contribution to the theory of how environment and behavior conjoin to impact vocal health. Research applies the Health Belief Model (HBM) and identifies key constructs (perceived susceptibility (fluoride exposure), perceived severity (vocal health outcomes), and perceived barriers (laryngeal discomfort)) utilized in shaping vocal performance outcomes [30]. The results support the use of the HBM to understand health behaviors in occupational settings, particularly among professional voice users. The findings extend the HBM by showing how environmental and behavioral factors jointly moderate the relationship between perceived laryngeal discomfort and health outcomes. Fluoride exposure and vocal frequency of use are disparate risk factors, but they act through their impact on laryngeal discomfort. Important for developing interventions for vocal health is that they must also address feelings of subjective physical sensations [6].

Perceived severity and barriers are shown to influence vocal performance outcomes in the study. Singers' assessments of vocal quality and range are strongly predicted by the singers' perceptions of the severity of their discomfort, suggesting that subjective appraisals are critical determinants of health outcome. This fits previously published research that underscores the psychological and physical effects of vocal strain.

Table 7: Path coefficient

| | Original sample (O) | Sample mean (M) | Standard deviation (STDEV) | T statistics (\|O/STDEV\|) | P values |
|---|---|---|---|---|---|
| H1: Fluoride Exposure Score -> Perceived Laryngeal Discomfort | 0.123 | 0.122 | 0.029 | 4.220 | 0.000 |
| H2:Perceived Laryngeal Discomfort -> Perceived Vocal Quality | 0.475 | 0.475 | 0.023 | 20.398 | 0.000 |
| H3:Perceived Laryngeal Discomfort -> Vocal Range Reduction | 0.453 | 0.453 | 0.023 | 19.686 | 0.000 |
| H4:Vocal Usage Frequency -> Perceived Laryngeal Discomfort | 0.222 | 0.223 | 0.025 | 8.952 | 0.000 |

**Table 8:** Mediation analysis. The table summarizes the results of the structural model, including all standardized path coefficients, t-values and p-values for path coefficients representing direct and indirect relationships.

| | Original sample (O) | Sample mean (M) | Standard deviation (STDEV) | T statistics (\|O/STDEV\|) | P values |
|---|---|---|---|---|---|
| H5a:Fluoride Exposure Score -> Perceived Laryngeal Discomfort -> Perceived Vocal Quality | 0.058 | 0.058 | 0.015 | 3.882 | 0.000 |
| H5b:Fluoride Exposure Score -> Perceived Laryngeal Discomfort -> Vocal Range Reduction | 0.056 | 0.056 | 0.014 | 3.886 | 0.000 |
| H6a:Vocal Usage Frequency -> Perceived Laryngeal Discomfort -> Perceived Vocal Quality | 0.106 | 0.106 | 0.014 | 7.487 | 0.000 |

This study's practical implications are of importance for vocal health professionals, opera organizations and public health policymakers. The findings have major implications for professional singers, who should take measures to prevent fluoride exposure, and make their vocal strain manageable to retain vocal quality and range. Strategies for minimizing environmental fluoride intake such as use of fluoride free oral hygiene products and consumption of low fluoride water sources should be emphasized in vocal health workshops as well as vocal health training programs.

The study by the scientists comes as a call to arms for vocal coaches and therapists, to ensure that perceived laryngeal discomfort is handled as a significant factor, inhibiting vocal performance. Singers' vocal health can be greatly improved by interventions aimed at decreasing discomfort, including hydration protocols, vocal rest schedules, and laryngeal massage. More than that, regular vocal health checkups can be performed by opera organizations to identify and fix discomfort in the larynx early before the disorder affects performance.

As such, public health policymakers should also start considering the broader implications of fluoride exposure for occupational voice users. While fluoride has been well known to have beneficial impact on the teeth, there needs to be further research into the possible negative side effects of fluoride on vocal health. Guidelines could be developed by policymakers concerning which safe fluoride levels should exist in drinking water for professional singers and other populations considered vulnerable.

Several limitations apply to this study. In addition, the sample only included professional opera singers in China, such that the findings may not generalize to other populations or geographic regions. The results should be validated by future research that extends the sampling frame to include singers from other cultural and environmental contexts.

Second, self-reported measures of fluoride exposure and vocal health outcomes were studied, which may introduce response bias. Accurate findings could be improved by objective measures of fluoride levels and vocal performance. Moreover, the study found strong relationships between the variables, but did not assess causality given the cross-sectional nature of the design. Deeper insights into dynamic relationships between fluoride exposure, vocal usage frequency and vocal health outcomes could be derived from longitudinal studies. Finally, the study mainly focused on the constructs of HBM. Using additional theoretical framework, such as self-determination theory or theory of planned behavior, could possibly increase understanding of the reasons of vocal health. Future research may include the role of psychological factors, including stress and anxiety, in how singers perceive laryngeal discomfort and how that can influence singers' perception of vocal performance.

## CONCLUSIONS

The results of this study suggest the presence of mediation by perceived laryngeal discomfort on the relationship between fluoride exposure and vocal health outcomes, through vocal usage frequency. Results support theoretical framework of the Health Belief Model and indicate that improvements in vocal health of professional singers will require concurrent modification of environmental and behavioral risk factors. Thus, this research highlights the potential long-term effects of fluoride exposure on vocal health and emphasizes the need for further studies, particularly involving occupational voice users like teachers and broadcasters. It suggests incorporating objective measures of vocal performance to enhance findings and offers practical strategies for preserving vocal quality. By exploring the dynamic interaction between environmental and behavioral factors, the study provides a foundation for developing targeted interventions to support the vocal health of opera singers and other professionals reliant on their voices.

## ACKNOWLEDGEMENTS

The authors appreciate the support of the Researchers Supporting Project number (RSPD2025R997), King Saud University, Riyadh, Saudi Arabia.

## FUNDING

The study was funded by the Researcher Supporting Project Number (RSPD2025R997), King Saud University, Riyadh, Saudi Arabia.

## CONFLICT OF INTERESTS

None

## REFERENCES


[1]. Lisboa, C. D., & Mello, M. G. d. S. (2018). Voice and speech signs and symptoms in individuals exposed to chemical agents: an analysis of medical records. Revista CEFAC, 20(2), 209-217.

[2]. Frangos, Z., Steffens, M., & Leask, J. (2018). Water fluoridation and the quality of information available online. International Dental Journal, 68(4), 253-261.

[3]. Howat, P., Binns, C., & Jancey, J. (2015). New international review supports community water fluoridation as an effective and safe dental health promotion measure. Health Promotion Journal of Australia, 26(1), 1-3.

[4]. Easley, M. W. (1990). The status of community water fluoridation in the United States. Public Health Reports, 105(4), 348.

[5]. Nallamuthu, A., Boominathan, P., Arunachalam, R., & Mariswamy, P. (2023). Outcomes of vocal hygiene program in facilitating vocal health in female school teachers with voice problems. Journal of voice, 37(2), 295. e211-295. e222.

[6]. Hall, M. K. (2023). Maternal Fluoride Exposure and Offspring IQ: An Investigation of the Potential Mediating Role of Thyroid Dysfunction in Pregnancy.

[7]. Rosenstock, I. M. (1974). The health belief model and preventive health behavior. Health Education Monographs, 2(4), 354-386.

[8]. Champion, V. L., & Skinner, C. S. (2008). The health belief model. Health Behavior and Health Education: Theory, research, and practice, 4, 45-65.

[9]. Norman, P., Conner, M., & Bell, R. (1999). The theory of planned behavior and smoking cessation. Health Psychology, 18(1), 89.

[10]. Brewer, N. T., Chapman, G. B., Gibbons, F. X., Gerrard, M., McCaul, K. D., & Weinstein, N. D. (2007). Meta-analysis of the relationship between risk perception and health behavior: the example of vaccination. Health Psychology, 26(2), 136.

[11]. Glanz, K., Rimer, B. K., & Viswanath, K. (2008). Theory, research, and practice in health behavior and health education.

[12]. De Onis, M., Onyango, A. W., Borghi, E., Garza, C., Yang, H., & Group, W. M. G. R. S. (2006). Comparison of the World Health Organization (WHO) Child Growth Standards and the National Center for Health Statistics/WHO international growth reference: implications for child health programmes. Public Health Nutrition, 9(7), 942-947.

[13]. Hunter, E., Price, D. A., Murphy, E., van der Loeff, I. S., Baker, K. F., Lendrem, D., Lendrem, C., Schmid, M. L., Pareja-Cebrian, L., & Welch, A. (2020). First experience of COVID-19 screening of health-care workers in England. The Lancet, 395(10234), e77-e78.

[13]. Rosenstock, I. M. (1974). Historical origins of the health belief model. The Health Belief Model and personal health behavior/Charles B. Slack, Inc.

[14]. Zou, G. J., Chen, Z. R., Wang, X. Q., Cui, Y. H., Li, F., Li, C. Q., ... & Huang, F. L. (2024). Microglial activation in the medial prefrontal cortex after remote fear recall participates in the regulation of auditory fear extinction. European Journal of Pharmacology, 176759.

[15]. Hunter, E. J., Cantor-Cutiva, L. C., van Leer, E., Van Mersbergen, M., Nanjundeswaran, C. D., Bottalico, P., Sandage, M. J., & Whitling, S. (2020). Toward a consensus description of vocal effort, vocal load, vocal loading, and vocal fatigue. Journal of Speech, Language, and Hearing Research, 63(2), 509-532.

[16]. Smith, R. A., Andrews, K. S., Brooks, D., Fedewa, S. A., Manassaram-Baptiste, D., Saslow, D., Brawley, O. W., & Wender, R. C. (2017). Cancer screening in the United States, 2017: a review of current American Cancer Society guidelines and current issues in cancer screening. CA: a cancer journal for clinicians, 67(2), 100-121.

[17]. Lee, Y., & Chen, A. N. (2019). The effects of progress cues and gender on online wait. Decision Support Systems, 123, 113070.

[18]. Jones, C. L., Jensen, J. D., Scherr, C. L., Brown, N. R., Christy, K., & Weaver, J. (2015). The health belief model as an explanatory framework in communication research: exploring parallel, serial, and moderated mediation. Health Communication, 30(6), 566-576.

[19]. Bai, Y., Wong, C. L., Peng, X., & So, W. K. (2020). Colonoscopy screening behaviour and associated factors amongst first-degree relatives of people with colorectal cancer in China: testing the health belief model using a cross-sectional design. International Journal of Environmental Research and Public Health, 17(14), 4927.

[20]. Hunter, E. J., Berardi, M. L., & van Mersbergen, M. (2021). Relationship between tasked vocal effort levels and measures of vocal intensity. Journal of Speech, Language, and Hearing Research, 64(6), 1829-1840.

[21]. Xu, K., An, N., Huang, H., Duan, L., Ma, J., Ding, J., He, T., Zhu, J., Li, Z., & Cheng, X. (2020). Fluoride exposure and intelligence in school-age children: evidence from different windows of exposure susceptibility. BMC Public Health, 20, 1-8.

[22]. O'Connell Ferster, A. P., & Hu, A. (2018). Perceptions of pain of laryngeal electromyography. The Laryngoscope, 128(4), 896-900.

[23]. Kasama, S. T., & Brasolotto, A. G. (2007). Vocal perception and life quality. Pró-Fono Revista de Atualizaçao Científica, 19, 19-28.

[24]. Pabon, P., Stallinga, R., Södersten, M., & Ternström, S. (2014). Effects on vocal range and voice quality of singing voice training: the classically trained female voice. Journal of Voice, 28(1), 36-51.

[25]. Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. Journal of Applied Psychology, 88(5), 879.

[26]. Fornell, C., & Larcker, D. F. (1981). Structural equation models with unobservable variables and measurement error: Algebra and statistics. In: Sage Publications Sage CA: Los Angeles, CA.

[27]. Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. European Business Review, 31(1), 2-24.

[28]. Lechien, J. R., Geneid, A., Bohlender, J. E., Cantarella, G., Avellaneda, J. C., Desuter, G., Sjogren, E. V., Finck, C., Hans, S., & Hess, M. (2023). Consensus for voice quality assessment in clinical practice: guidelines of the European Laryngological Society and Union of the European Phoniatricians. European Archives of Oto-Rhino-Laryngology, 280(12), 5459-5473.

[29]. Uloza, V., Ulozaitė-Stanienė, N., Petrauskas, T., & Kregždytė, R. (2023). Accuracy of acoustic voice quality index captured with a smartphone–measurements with added ambient noise. Journal of Voice, 37(3), 465. e419-465. e426.

[30]. Schaeffler, F., Parry, A. M., Beck, J., Rees, M., Schaeffler, S., & Whittaker, T. (2023). Comparing vocal health and attitudes to voice care in primary teachers and voiceover artists–a survey study using the health belief model. Journal of Voice. 2023 Mar 18:S0892-1997(23) 00039-5.