EFFECT OF CHEMICAL SUBSTANCE EXPOSURE ON VOICE

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August 2022

CERTIFICAT CERTIFICATE

This is to certify that this dissertation entitled **"Effect of chemical substance exposure on voice"** is bonafide work submitted in part fulfilment for the degree of Master of Science (Speech-Language Pathology) of the student with Registration Number 20SLP013. This has been carried out under my guidance and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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August, 2022

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DECLARATION

This is to certify that this dissertation entitled **"Effect of chemical substance exposure on voice"** is the result of my own study under the guidance of Dr. Dr. R Rajasudhakar, Associate Professor, Department of Speech-language Sciences, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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CHAPTER I

INTRODUCTION

What is voice?

The sound produced due to the vibration of the vocal fold present in the larynx is defined as voice. The recognition of a speaker can be made by his or her voice as it gets shaped into a unique acoustic form by the dimensions of the vocal tract. (Aronson, 2009). It constitutes parameters such as pitch which is the perceptual correlate of frequency, loudness which is the perceptual correlate of loudness, quality the perceptual correlate of complexity and variability (Aronson, 2009).

According to Johnson, Brown and Curtis et al. (1965) a normal sounding voice is to be of a) pleasant quality with the absence of noise components; b) age and gender appropriateness needs to be present for the particular pitch; c) the communicative event decides the loudness of the voice. It should not be too loud or too soft; d) it needs to be flexible enough to produce variations in pitch and loudness to place emphasis or to satisfy communicative context need and e) it needs to meet the person's social or occupational needs.

When a person's individual and professional needs are met there, ones voice can be defined to be healthy. It helps identify and distinguish people and also serves as a tool for communication. It needs to be appropriate for an individuals gender, age, personality traits, emotional state and cultural heritage. It changes in every phase of life which includes birth, childhood, adolescence, adulthood and oldage as said by Jardim et al. (2007).

Production of Voice

There are three subsystems involved and essential for the production of voice (Schneider and Satalof, 2007).The power source for voice production comes from the respiratory breathe support. The diaphragmatic breathing pattern balances the use of expiratory and inspiratory muscles thus leading to good speech production. The breath support given by the respiratory system is later modified into phonation at the level of the larynx. The quality of voice produced is usually a result of proper phonation. Any abnormality would lead the voice to be perceived as hoarse, breathy, rough, pitch breaks, and diplophonic. The sound is later shaped acoustically by the vocal tract to produce vocal resonance. It is important to produce this appropriate forward focus in order to balance oral-nasal resonance. Hence, appropriate coordination is to be present between these subsystems in order to produce voice efficiently.

Abnormal Voice

Abnormal voice may result when the voice fails to be of appropriate pitch, loudness and quality according to the needs of an individual, appropriate for an individual’s age, gender, cultural background or geographic location. When a deviancy is noticed in terms of voice quality, pitch and loudness one may suspect the presence of a voice disorder as described by Aronson (2009).

Nooromplakal et al. (2011) said that abnormalities in voice may be due to the result of abnormalities in structure or functioning of those involved in production of voice. Any negative deviation in voice can be defined as dysphonia. Aronson (2009) defined dysphonia as any such condition where there may excessively high or low pitches, inadequate or excessive loudness or variations in quality of voice in terms of harshness, hoarseness or breathiness. It may also be due to lack of variability in pitch or loudness. These bring about changes in the psychoacoustic parameters of pitch, loudness, quality and variability.

Prevalance of voice disorders across various groups

An occupational voice disorders are those that develop mainly due to work place environment. Teachers, manufacturing/factory workers, salespersons and singers are the populations who are at greatest risk for developing occupational voice disorders (Williams, 2003).

In a retrospective investigation conducted by Herrington-Hall et al. (1988) involving around 1262 patients to describe the laryngeal pathologies and their distribution across three variables: sex, age and occupation across the type of environment they lived in patients who seeked treatment. It was noticed through this study that the common largygeal pathologoies present were nodules (21.6%), edema (14.1%), polyps (11.4%), cancer (9.7%), vocal fold paralysis (8.1%), and dysphonia in conjunction with a normal larynx (7.9%). Females were more prone to develop voice disorders as compared to males. Pathologies like nodules and psychogenic voice disorders were more common in females whereas cancer and luekoplakia were more common in males. It was found that 57% of patients aged over 45 years of age and 22.4% were aged over 64 of years of age. The ten most prevelant occupations prone to voice disorders are people who were old and retired, homemaker, factory workers, executive managers, teachers, students, secretary, singers and nurses as compared to the other professionals. Certain unemployed people also had voice problem. It was noticed that the factory workers were one of the top five professionals who were found to have voice problem which may be attributed to the fact of raising their voices while speaking in noisy environment or due to inhalation of toxic chemicals, fumes and dust present in the work environment.

Przysiezny et al. (2015) described a condition called Work Related Voice Disorder has been defined as the condition where there are negative changes in the laryngeal structures and voice caused due to the usage of voice in daily work environment. It’s a condition commonly seen in professional voice users. Hence, it impairs their usage of voice in communicative and work related activities. The common signs of this disorder includes fatigue, hoarseness, dry mouth, higher efforts to speak, loss of voice completely or partially, pain while talking or lack of projection in volume while talking. This is a condition that highlights voice disorder caused due to usage of voice in daily work environment. They described it to be a condition most commonly found in professional voice users.

There are many studies that highlight the correlation between the profession and daily use of voice in work environment along with the risk of developing voice disorders. It has also been seen that most of these professional voice users approach speech language pathologists for diagnosing and treating their condition as the disorder directly impacts their daily living. However, there have been very few studies that highlight the risk factors that are present in the work environment which may produce harmful effects on the voice organs as said by Ohlsson (1983).

It can be concluded from these studies that there are other groups of people apart from professional voice users who are at risk for developing voice disorder and dysphonic symptoms due to environmental factors like noisy environment or exposure to fumes and chemicals in the work place environment. Hence, the occupational environment and vocal behaviours needs to be studied in further.

Assessment of voice

Assesssment is crucial step for selecting appropriate management strategies. It gives a detailed idea about the nature, course and the cause of the disorder. Uloza, Vegiene and Saferis (2013) highlighted the need for multidimensional assessment and evaluation of dysphonia and voice related complaints must include case history, patients perceptual complaints laryngeal examination, perceptual analysis of the severity of dysphonia and the quality of voice, acoustic evaluation, aerodynamic measures and also self evaluation of the voice disorder and it's effect on their daily life and activities in terms of frequency and severity. An example of the self perceived instruments would include the Vocal Tract Discomfort Scale(VTDS) developed by Mathieson in 1993.

Lopes et al. (2015) noticed that the treatment provided for a particular voice disorder may target to reduce the perception of symptoms along with improving voice quality. Symptoms present along with the voice disorder affect the quality of life of the individual directly or indirectly. Hence, it is important to consider self perceived symptoms during evaluation and treatment. The VTDS developed by Mathiesson (1993) was a self perceptual vocal symptoms assessment tool related to discomfortness that would be present in the vocal tract.

A laryngeal pathology causing changes in the glottal or vibratory patterns of the vocal fold would alter the acoustic signal patterns radiated through the lips. It helps us non invasively document the correlation between the perceived vocal quality and changes in acoustic signal due to abnormal vibratory patterns. Hence, acoustic analysis has gained attention in the screening, evaluation, and treatment of voice disorders. It has also proven to be useful to compare the prognosis in a condition when using two different strategies for management and also document the changes through the course of management (Hillenbrand, 2011).

Brief introduction on hazards caused due to isocyanates

An alarming incident that released harmful gases into the atmosphere happened in Bhopal in pesticide manufacturing industry due to the leakage of methyl isocynate (MIC) and other products released due to MIC hydrolysis in the year 1984. A number people who had been directly exposed to this leakage reported of symptoms such as eye irritation, burning throat, eyes and nose, choking sensation. Few developed certain nuerologiocal symptoms also which included panic, depression, confusion, agitation, apathy, and convulsions. Autopsic studies conducted on those who were dead due to the exposure revealed that they had severe necrotizing lesions which affected the bronchioles, alveoli, capillaries in the lung, and lining of the upper respiratory passage. This substance has also been found to have toxic effects on genes. It also affected the immunological system thus making people more prone to diseases and also causing autoimmune disorders (Bucher, 1987). Hence, on a long term exposure to this particular chemical in smaller concentrations may have effects on voice also.

Studies have documented the voice symptoms and voice disorders associated with workplace exposure to chemicals. Prolonged hoarseness, tightness of the chest, episodes of aphonia accompanied by pharyngeal irritation was the major symptoms of a case that was exposed to formaldehyde for a period of nine years. The subject was advised to not get exposed to the same for a period of twenty four hours after which it was noticed that the symptoms had lessened (Roto & Sala, 1996). Oedematous pharyngo-laryngitis was due to prolonged occupational exposure to Freon gas. It was also accompanied by odynophagia, dysphonia, and breathless as found by Tanturri, Pia, and Benzi (1988).

Need for the Study

There has been very limited literature which throws light on the non-vocal professionals who are exposed to chemical substances which cause changes in their voice either during the exposure or after a certain period of time. There are very few studies which have explored self-perceived vocal symptoms reported by these individuals who have been exposed to chemical substances, fumes, vapours and other irritants in their occupational environment. Hence, the study was planned to estimate the effect of exposure of chemical substance exposure on voice.

The most commonly used instruments to evaluate the self perception voice symptoms is the Voice handicap Index (VHI) which does not assess the pain and discomfort symptoms in individuals prone to develop voice disorders or those with voice disorders. Standardized and validated tools are required to document the self perceptual vocal symptoms in individuals with voice disorder as said by Darawsheh et al. (2018). The VTDS scale documents the sensory symptoms experienced by these individuals which cannot be assessed using other tools. Symptoms detected through VTDs may help us predict the vocal health conditions thus preventing further structural damage to the vocal structures as said by Darawsheh et al. (2020).

In this particular study the VTD scale was employed to evaluate the vocal tract symptoms perceived in those exposed to chemicals and compare it with those who have not been exposed to chemicals as they consist of 8 qualitative descriptors which are burning, tight, dry, aching, tickling, sore, irritable and lump in the throat. Most of these qualitative descriptors or symptoms have been previously reported in literature in those individuals exposed to a variety of chemicals substances. Dryness of throat, soreness of throat, burning sensation of the throat and presence of lump in throat were reported by individuals who were exposed to a wide range of chemical substances in a study done by Lisboa and Mello (2018). Throat burning and throat dryness was reported when participants were exposed to the fumes that came from burning of incense sticks in a study done by Messalam et al. (2015).

Aim of the study

The present study aimed to empirically document the effect of exposure of chemical substances on various parameter of voice.

Objectives of the study

1. To document the self -perceived voice symptoms of subjects who are exposed to chemical substances using Vocal Tract Discomfort Scale (VTDS).

2. To evaluate acoustic parameters of voice using PRAAT software.

3. To compare the self -perceived voice symptoms using VTDS between subjects who were exposed to chemical substances and their normal controls.

4. To compare the acoustic parameters of voice between subjects who were exposed to chemical substances and their normal controls.

CHAPTER II

REVIEW OF LITERATURE

Lisboa and Mello (2018) analysed 139 medical records in order to conduct a descriptive and exploratory study in order to document the speech and voice signs in individuals exposed to chemical agents. All of the cases were analysed in four stages wherein the first stage involved in filling up of the details of participants such as demographic data, speech and voice signs reported, chemical agent involved in the exposure followed by application of the inclusion and exclusion criterias. The information was manually collected after which it was put into a table in a descriptive manner. All cases who participated in the study were 18 years or above and did not report to have any voice disorders prior to the exposure to chemical substances. A total of 75 cases were taken up for the study as they met the inclusion criteria out of which 12 (4 men and 8 women) had information regarding speech and voice signs in the following age ranges 34–35 years, 36–40 years, 41–45 years, 46–50 years, 51–55 years and 56–59 years. They have considered 7 health agents, 1 production operator, 1 smelting assistant, 1 metallurgist, 1 chemical technician and 1 mechanic who were exposed to the following chemicals 7 insecticides, 1 toluene, 1 toluene, benzene, and trichloroethylene, 1 acetone, turpentine, and paints, 1 gasoline, fluorine, aluminium sulphate, and chlorine and metallic lead for the following durations 2 years, 5 years, 8 years, 11 years, 12 years, 14 years, 17 years and 24 years. Hoarseness was present in 3 individuals, 2 individuals reported loss of voice, 1 reported chronic inflammation of the throat, 1 reported to have soreness throat, 1 reported to have secretions along with burning sensation in the throat, 1 reported to have dryness of the mouth and throat, one reported to have lump in the throat along with some difficulty in swallowing and one reported to have articulatory difficulties. Difficulty in verbal expression was reported by one individual. It was concluded that chemical irritants may cause direct speech and voice problems. Individuals who reported to have sore throat were only referred for further evaluations and it was concluded by having trained professionals such as speech language pathologist or otorhinolaryngologist would help identify those individuals who require further evaluations.

2.1 Disorders/Diseases reported to due Chemical substances /Irritants /Fumes/ Dust

1) Reactive Airway Dysfunction Syndrome

Hannu, Riihimaki and Piirila (2009) described a case of a 48 year old female chemistry teacher who had 16 years of work experience. She did not report to have any breathing difficulty prior to the inhalation of fumes produced as a mixture of powdered aluminium and powdered iodine with water. The combination of the substances causes an oxidation-reduction reactions to occur. She has worn no protective equipment when being exposed to those fumes after which she experienced cough, dyspnoea, and hoarseness of voice. On performing bronchoscopy after a period of 9 months mild diffuse redness was present on her bronchial mucous membranes along with persistent hoarseness of voice. On performing biopsy it was noticed that she had slight chronic infiltration. Spirometric evaluation revealed mild restrictions. Histamine challenge test was performed and it was found that she had slight bronchial hyperesponsiveness which persisted even after a period of 15 months. Her hoarseness of voice persisted which worsened during cough. The criteria for diagnosing as RADS (Reactive Airway Dysfunction Syndrome) proposed by Brooks et al. (1985) which is a condition in which the respiratory symptoms to develop after 24 hours only on single exposure to gas or smoke and must be persistent for atleast 3 months. The patient must not have had any other respiratory issues prior to the exposure. Pulmonary function tests might show presence of airflow obstruction, methacholine challenge testing should be positive. Other respiratory and pulmonary diseases need to be ruled out. Having fulfilled this criteria the client was diagnosed to have RADS. This has been one of the first case of RADS reported post exposure to oxidation reduction reactions in the chemistry lab. It was concluded from this study that experiments performed in the chemistry lab are not always risk free and hence appropriate protective equipment needs to be used while performing such experiments in the chemistry lab.

2) Occupational Laryngitis

Occupational laryngitis is mainly caused due to exposure to irritants, fumes and dust which causes chronic inflammation of laryngeal mucosa. Hannu, Piipari and Toskala (2006) described a case of a 50 year old non smoker man who had been exposed to fumes that was present during welding of metals for the past 24 years and who occasionally used protective equipment. He did not have any respiratory issues prior, nor any atopy (allergic reaction). He reported to suddenly develop sore throat and retrosternal pain nine months before being evaluated. He was put on antibiotics when he was suspected to have pharyngitis and when there was no improvement noticed, he was further referred to an otorhinolaryngologist. He underwent indirect laryngoscopy that revealed mild irritation of the mucous membranes. It was found that the client had worsening of symptoms towards the end of the day. Skin-prick tests to common environmental allergens and metals were done to identify possible allergen. On undergoing the welding challenge which carried out in a 8.5 m3 welding chamber with isolated ventilation for a period of 30 minutes. Bronchial hyper responsiveness to histamine was assessed. Acoustic rhinomanometry, flow-volume spirometry was done with a pneumotachograph spirometer connected to a microcomputer. Larngygoscopic evaluation was done before and after the challenge test and signs of edema and erythrema were scored on a four point rating scale. It was found that he had no allergic reactions to metals, normal spirometric findings and no bronchial hyper responsiveness in the histamine challenge. Both edema and erythema was scored to be moderate in the laryngeal and the mucosal regions. The same results where obtained when the tests were performed after 2 weeks when the patient was sick except on edema and erythema which had increased based on which the diagnosis of an occupational laryngitis was made. His peak expiratory airflow volumes decreased by 19%, however there was no change in his forced expiratory volume. Avoiding the welding atmosphere brought about significant relief from the symptom and was advised to do so. The patients's voice was also perceived to be hoarse. During evaluation it was found that he developed edema, erythema and hoarseness of voice. He was diagnosed to have occupational laryngitis of immediate hypersensitive type that developed due to the exposure to fumes. He was advised to completely prevent himself from being exposed to welding fumes. Hence, it was concluded by the author that welding fumes could be a potential cause of occupational laryngitis. Further research in this particular field may warrant the full understanding of the pathophysiology.

3) Work Induced Irritable Larynx Syndrome

Anderson (2015) conducted a literature review on Work Associated Irritable Larynx Syndrome (WILS) which is a condition caused due to the exposure to irritants that are present at the workplace. WILS can be defined as a state of chronic hypertonicity of the larynx due to repeated exposure to irritants and can lead hyperkinetic laryngeal dysfunction on subsequent exposures. The diagnosis of WILS is made through clinical examination where there is presence of excessive laryngeal tension post exposure to irritants/chemicals along with one or more of the following symptoms: (1) muscle tension dysphonia (2) chronic cough (3) episodic laryngospasm (airway obstruction) and (4) globus pharyngeus. The author has also found that 1 out of 5 of those who visited an occupation lung clinic had WILS, out of which 76% were females who had other issues like gastro esophagesal reflux disorder. The main agents that caused WILS were identified to be cleaning agents, isocynates, formaldehyde, fumes, exhaust and dyes. The main cause of WILS is multifactorial and the three main pathophysiological conditions associated with it are neuronal plasticity, inflammatory process and psychological factors. The diagnosis of WILS can be made by obtaining a detailed case history regarding vocal fold dysfunction and GERD along the timeline of the symptoms present. The author has explained that the onset of the symptom is immediate to the exposure of the irritants and subside when the irritant is no longer present. Also, symptom intensity is directly related to concentration of irritants present. The confirmation can also be made by employing procedures like laryngeal sensation include hypertonic saline challenge, endoscopic evaluation with sensory testing and reflex cough sensitivity testing. The metacholine allergic testing can be carried out for testing allergies or asthma. Spirometric findings in these individuals could be normal except when there are hard vocal fold adductions. Other evaluations like reflux symptom index can be carried out to confirm the presence of GERD and Voice Handicap Index can be done to understand the major voice complaints. WILS easily be diagnosed using laryngeal endoscopy and provocation testing. The symptoms were dependent on the dosage and duration of irritant exposure. Dysphonia, cough, globus or dyspnea, mucous production, irritation and blocking sensation were the main symptoms reported post exposure which reduced when the exposure was avoided. Management of WILS can be mainly done through not exposing them to the irritant, and by using cognitive and behavioural strategies by a speech language pathologist. Efficiently managing other associated conditions such as GERD would also bring immediate relief to such patients.

4) Irritant Induced Vocal Cord Dysfunction

Vocal cord dysfunction is the term given to the collection of symptoms such as dyspnea, cough, chest pain accompanied by paradoxical vocal cord motion during inspiration. When this condition is caused due to irritants such as Ammonia, pungent odors, fumes, smoke and dust are irritants it would be termed as irritant induced vocal cord dysfunction (IVCD).

Allan et al. (2006) described a case of 49 year old fire fighter who had been diagnosed to have IVCD post exposure to high concentration of chlorine gas in accident spot without any protective equipment. He developed eye irritation, itchy throat and vocal hoarseness on in the area where the accident had taken place itself. On administering the laryngoscopic procedure it was found that there were no structural abnormalities but there was a significant vocal cord adduction to permit inspiratory release of air only through a small triangular portion. Questionnaires were used over the following ensuing weeks to track the worsening of dyspnea symptoms related to the post chlorine incident baseline. Serial pulmonary function testing (PFT) in each of the subsequent 2 weeks showed worsening inspiratory loop truncation parallel to his dyspnea scores due to which the authors concluded it was because of the exposure to high concentration of chlorine. The authors have concluded that due to the lack of protective equipment in high concentrations of the chlorine gas that was released in the accident area the participant of this study has developed IVCD which is supported by the gradual decline in his respiratory status post exposure with no perceptual complaint.

This article highlights the need for the need for evaluation post exposure to chemical compounds irrespective of whether protective equipment had been used during the time of exposure.

5) Laryngeal Cancer

Ramroth et al. (2008) conducted a population based control study in South-West Germany on laryngeal cancer to investigate the effect of exposure to wood dust on developing or being a major risk factor for the development of laryngeal cancer from 1st May 1998. They have considered exposure to both hardwood and softwood dust. Sub sites of tumours have been distinguished in terms of glottis, subglottis and supraglottis. They identified around 257 case samples within the age range 20 years and 80 years by the end of 31st December 2000. Their age matched controls were selected after taking approval from the participants in the ratio of 3:1. Interviews were conducted with the controls and the experimentals. Information regarding family history of cancer, smoking, occupational exposure and alcohol consumption, were all collected using standardised questionnaires which were similar to those used previously. A detailed history of the occupational exposure was considered by taking into account exposure substance checklist (SCL) which took into account all carcinogenic agents of the upper respiratory tract. 34 supplementary specific job questionnaires (JSQ) which addressed specific exposure in job branches or industry and also considering all jobs held for a period of atleast 6 months was administered. It was found that the mean age for the controls 62.7 years and cases was 62.5 years. There was a strong effect that was found while considering wood dust exposure as a risk for laryngeal cancer especially the hardwood. An increased risk was found by performing dose-response analysis. Hence, this study highlights that wood dust is an additional independent risk for development laryngeal cancer.

6) Vocal Allergies

Vocal allergies have always been seen as a by product of rhinitis or sinusitis. The relationship between vocal allergies and dysphonia has now received recent interest in literature. It has been found that vocal allergies may cause dysphonia in individuals in the of both absence of sinusitis and lower airway allergic response. The vocal complaints of allergic and non allergic individuals were compared and it was found that the allergic group had more severe vocal complaints as compared to the non allergic group. Further research needs to be conducted in order to understand the nueropathophysiological pathways associated with vocal allergies (Roth and Ferguson, 2010)

2.4 Effects of isocyanates on general health

Verschoor and Verschoor (2014) conducted a review study in order to understand the effects of isocynates on health. It causes many effects on health such as the digestive system, irritation of the nose, throat and eyes. It was found that a single high concentration exposure to isocyanate was sufficient to cause Reactive Airway Dysfunction Syndrome, occupational rhinitis and asthma. At low levels of isocyanates sensitisation has been reported to occur where there are adverse health effects that are caused on the upper respiratory pathways. The US National Institute for Occupational Safety and Health has limited the amount of permissible isocyanate exposure limit to be 0.05 mg/m3 or 0.005 ppm. Decreased values on forced expiratory volume and forced vital capacity were other abnormalities found in these individuals. Sometimes chronic persisting lung diseases and cancer was also reported in these patients. It could also irritate the nose, throat and the upper airways and also the digestive tract. Apart from the occupational group who are exposed to different concentrations of isocyanates every day, the effects of the chemical have been found negatively on the non occupational group as well. Non-occupational group consisted of a group of 203 school going children who were accidently exposed to xylene and isocyanate developed dyspnea, dizziness, nausea and sore throat.

The present study consist of paint which is mainly composed of polyurethanes and isocyanates. Hence, one can imagine the adverse health effects the workers of that particular factory may have.

2.3 Studies highlighting Voice Symptoms or Vocal Symptoms

1) Caused due to Fumes

Ohlsson, et al. (1987) studied the frequency of throat and voice problems, vocal behaviour and vocal demands between a group of 8 non smoking welders and a group of 8 office clerks. The participants were age and gender matched. The participants of both the groups were asked to fill a questionarre that consisted of 20 questions regarding their vocal symptoms, vocal habits, vocal effort and subjective feeling of their voice problems. It was found that the welders reported to have more voice abnormalities mainly hoarseness and vocal fatigue than the clerks due to the exposure to fumes and excessive vocal demands due to the presence of noise in the work environment. A perceptual evaluation was carried out by asking the participants of both groups to sustain a phonation of the vowel /a/ which was recorded using Revox A -77 tape recorder. It was judged for hypofunctional/hyperfunctional voice by a group of 5 trained speech language pathologists. Perceptually the welders had more hyperfunctional voices along with strain and creakiness as compared to the clerks. The long term average spectrum was performed in the frequency range of 0-1 KHz and 1-5 KHz and it was found that the welders had a lower ratio of energy 0-1/1-5 kHz than do the voice of the clerks which was found to be hypofunctional on LTAS. The laryngoscopic evaluation revealed no such evident differences between the two groups. The results of the study contribute to the evidence that vocal symptoms perceived by these individuals may be attributed to the presence of dust, gas, fumes and the hyperfunctional voice may be due to the excessive vocal demands while working in noisy environment. Hence, future investigation can be carried out to study the relationship between work environment and voice disorders or vocal complaints by combining long term average spectrum and auditory analysis techniques.

Burning of incense sticks is very common in parts of Saudi Arabia. The burning of incense sticks produced both particulate carbon monoxide, oxides of nitrogen, formaldehyde, sulphur dioxide, and gas emissions. Another recent study conducted by Mesallam et al. (2015) examined the exposure effects for a short period of time due to the burning incense sticks on laryngeal symptoms and voice acoustics. A total of 72 participants considered for the study where 30 were males and 42 were females within the age range of 18 to 60 years. Individuals who did not report to have voice disorders, pulmonary issues, gastro esophageal reflux disorder at the time of the study were taken up. All the participants were seated in a closed room and exposed to the burning of 1gram of incense when the seated at a distance of 1 metre away for a duration of 5 minutes. Symptom analysis using direct interview of the symptoms that persisted and acoustic voice analysis was carried out using Multidimensional Voice Program (MDVP Model 4305, Kay Elemetrics Corp., Lincoln Park, New Jersey) at pre and post exposure. It was found that majority of the subjects did not report to have perceptual symptoms post exposure but 27.8% had symptoms out of which nine participants reported to have throat burning, seven participants had throat dryness and three participants reported to have both while another participant reported to have throat dryness along with shortness of breath. The acoustic analysis was carried out for the following parameters which are jitter, shimmer, and noise to harmonic ratio. After considering gender differences it was found frequency parameters increased post exposure as compared to baseline though not statistically significant. The study was conducted with a small sample size who were only exposed to the burning of incense sticks for a short duration. The study also lacks comparison with control group. This study serves as a basis for conducting other studies to understand the effects of prolonged exposure to incense burning on laryngeal and voice parameters. It can be concluded from the above study that despite the subjects being exposed to incense burning for a short duration there were perceptual symptoms and also mild variations in voice parameters as reported by the authors.

2) Due to Exposure to Hazardous Gases

Sulphur mustard gas was used in warfare by both military and civilian population by Iraqi forces in the Iraq–Iran war (1983–1988). It is known for its toxicity even at low levels of exposure. Heydari and Ghanei (2011) have identified sulphur mustard gas to be a potential substance to produce harmful effects on the aerodynamics of speech. As no attempt has been made yet to study the effect of chemical substances on the speech aerodynamics as claimed by the authors, this study was carried out to evaluate the speech aerodynamics in those individuals exposed to sulphur mustard gas during World War 1. A controlled comparative study was done on 19 men exposed to chemicals with a mean age of 40 years and 20 controls with a mean age of 41 years was not exposed to any chemicals. All participants were non-smoking healthy individuals without pulmonary or respiratory disease. The Glasgow Airflow Measurement System (known as ST1 dysphonia) developed by G.M. Instruments Ltd. and Department of

Clinical Physics and Bioengineering (Glasgow, UK), was used to measure the various parameters. The following parameters were recorded giving the clients appropriate instructions: mean air flow rate, vital capacity, maximum phonation time, phonation volume, vocal velocity index, total expired volume and phonation quotient giving the clients appropriate instructions. It was noticed that the results obtained were lower in value in those exposed to sulphur mustard gas in the following parameters like vital capacity, maximum phonation time, phonation volume and total expired volume. Vocal velocity index and phonation quotient was higher in exposed experimental group as compared to controls. This indicated that those exposed to chemicals had pulmonary deficits which did not support breathing that is required for speech. The inclusion of only 19 participants and lack of acoustic analysis in this study made it difficult to make further conclusions. This study helps speech language pathologist in understanding the main pathophysiological changes that occur on speech aerodynamics in individuals exposed to chemical substances

3) Due to Exposure to Dust

A study was conducted by Geneid et al. (2009) in order to assess acute voice and throat symptoms related to organic dust exposure. He considered five females and four males whose age ranged from 26 to 40 years who were suspected to have occupational rhinitis or asthma. Skin prick test was performed in order to eliminate possible allergic reactions in all individuals. None of these individuals reported to have upper respiratory tract infections at the time of evaluation. All of these individuals were exposed to organic dust in a 6 m3 air tight ventilated chamber for a period of 30 minutes. They were all given a task to blow (2-bar) air which was compressed into a cup of dust in every minute. The subjective acute voice and throat symptoms were documented by the subject before and after exposure to organic dust using a visual analogue scale of 0 to 10. It consisted of questions regarding overstrain in voice, hoarseness or huskiness in voice, lump in throat, dryness in the throat, throat clearing habits, choking sensation, creakiness and presence of voice breaks, difficulty starting a phonation and shortness of breath. The voice samples were recorded pre and post exposure using portable hard disk player (iRiver 140) with a sampling rate of 44.1 kHz. A weather forecast passage of 72 meaningful words were read three times by the participants. Two speech language pathologist carried out perceptual assessment using the visual analogue scale after being blinded to when the recording was performed. An otolaryngologist carried out mirror laryngoscopy within 15 minutes of exposure to score the mucosal reactions using the scoring criteria of Hytonen et al. (1996). The participants reported hoarse, husky or weak voice, felt that their voice did not resonate and due to excessive tension they needed to add extra effort while speaking or starting a phonation. In addition to which subjects had feelings of shortness of breath or the need to gasp for air. Five of the subjects developed asthmatic symptoms and four developed occupational rhinitis. No differences were found in voice by the speech language pathologist on perceptual assessment post exposure. No significant changes were found on laryngeal mirror examinations post exposure. The findings of study support the idea that human laryngeal mucosa has the potential ability to generate allergic reactions to dust which may not be perceived by the speech language pathologist. The study also throws light on the subjective voice and throat complaints due to exposure to dust/irritants. Further study needs to be conducted in future with specific types of organic dust using larger number of participants who can be evaluated using acoustic measurements and also correlated with other subjective and perceptual measurements.

Trees are cut into wood in saw mill industries. This process produces lots of wood dust thus being hazardous to the upper respiratory tracts. A recent study conducted by Varghese et al. (2019) to investigate the acoustic voice characteristics of saw mill workers. Thirty saw mill workers between the age range of 25 to 35 years were taken up for the study and their acoustic parameters were compared with age and gender matched controls. They were asked to phonate vowel /a/ at a comfortable pitch and loudness which was recorded using a portable digital Sony recorder- ICD UX81F using a constant mouth-to-microphone distance of 10 cm and 45° off-axis positioning. The phonation sample was line-fed into the module of CSL 4500 (Kay Pentax, New Jersey) at 22k Hz sampling rate. The signal was displayed on the Multi Dimensional Voice Program (MDVP) program of the CSL 4500 and a 3 sec steady portion of the phonated vowel was identified. The acoustic analysis was done for the study portion of the vowel phonation. Mean fundamental frequency, jitter % and relative average perturbation were taken up for between group comparisons. There was significant difference in all three parameters between the controls and saw mill workers. This indicates that saw mill workers are at greater pre disposing risk factors to develop voice disorders due to the exposure to saw dust in the work environment. Counselling and usage of protective equipment along with practising vocal hygiene strategies need to employed for saw mill workers.

4) Due to Chemical Agents

a) In Industries and Factories

Chemicals like ammonia and sulphuric acid are commonly used in latex manufacturing industry. Nooromplakal et al. (2011) examined the association between these chemicals on voice and its subsystems on individuals working in a latex manufacturing company where they were exposed to above mentioned chemical agents in high concentrations for long terms. The experimental group consisted of forty three male participants between the age range of 35 and 48 years. All the participants did not have any voice disorders at the time of the study. The experimental group individuals who worked for a minimum of 8 hours in a latex manufacturing company for a period of 10 years. Control group consisted of forty three male participants between the age range of 35 and 50 years of age who did not have any voice disorders at the time of evalution. Both groups of subjects were given four tasks which consisted of reading a monologue, s/z ratio, maximium phonation duration of /a/, /i/, /u/ and reading meaningful words which include /a/, /i/, and /u/ in VCV context. A sampling frequency of 44 kHz was used in the Praat software version 5.1.22 (Weenink & Boersma, 2009) using frontoech external microphone from which acoustic parameters such as fundamental frequency (FO), shimmer dB, jitter percent, speaking fundamental frequency (SFF), and harmonic to noise ratio (HNR) were measured. The s/z ratio was measured using a stop watch. It was found that lower F0 values, speaking fundamental frequency and on jitter values were lowered as compared to the control group. There were no significant differences in the shimmer and HNR as observed in this study. The experimental group had lower measures on s/z ratio as compared to the control group. The maxiumum phonation duration measures were also found to be lower on in the experimental as compared to the control group. Hence, it can be concluded from the present study that there are effects on the respiratory and phonatory systems due to prolonged exposure to chemicals. Good vocal hygiene measures along with reducing the duration of exposure to the chemical irritants as warranted by the authors to such populations who are at risk. Future research can be targeted in order to correlate acoustic analysis with direct visualisation methods.

Kasbi et al. (2022) examined the effects of chlorine exposure on laryngeal and voice symptoms. The participants were 138 workers (13 females, 125 males) with a mean age of 30 years who worked in a chlorine chemical factory who were exposed to 2ppm which peaked upto 300 ppm in certain parts of the factory. All workers used protective equipment such as clothing and face masks when the levels peaked to 300 ppm and compared their laryngeal and voice symptoms with 70 workers with a mean age of 32 years (three females, 67 males workers) of a non chlorine factory. Two questionnaires were provided to both the groups. Questionnaire 1 collected information regarding the work place vocal health. It was aimed to collect information on various risk factors associated with the laryngeal health and also included demographic details, job characteristics and work place characteristics as defined by the worker. Questionnaire 2 aimed to collect information about the voice and the laryngeal symptoms of the employee. It consisted of three parts. Part 1 consisted of questions regarding the presence of voice problem at that particular time and rating done on a 4 point rating scale where 0 implied “rarely” and 3 implied “always”. Part 2 collected information regarding the presence of voice problems in the entire month. Part 3 consisted of questions regarding the effects of voice on emotions and communication aspects. The questionnaires used in this study were developed by Jazem et al. (2017) to investigate voice problems among workers of beauty salons. 19% of the workers of the chlorine factory and 7% of non chlorine factory workers reported to have laryngeal and voice complaints. Dry throat, hoarseness, cough or throat clearing, vocal fatigue, feeling of muscle spasm, effortful voice and aphonia along with other side effects of voice complaints such as inability to speak in crowded places, feeling of low esteem while talking, requiring to repeat sentences so that others comprehend their speech and feeling of anxietywhile speaking were reported in both groups. The most commonly reported symptom was dry cough and the least reported symptom was aphonia. It was also concluded that the voice issues could also be due to the lack of humidity and inadequate water intake during working hours. Hence, it could be inferred from the above study that workers of the chlorine factory had more laryngeal and voice complaints as compared to non chlorine factory workers. It was hinted by authors that there was a probability of the voice symptoms to be increased by 1.09 times for every one year increase in age. The findings of the above study indicated that exposure to chlorine for prolonged periods of time could lead to laryngeal and voice complaints. The use of self-report questionnaires and lack of acoustic analysis, physiological assessment and auditory-perceptual evaluation are the main limitations of the study. The concentration levels of chlorine across various setting was not controlled in the study. Hence, further research needs to be carried out in using these parameters in order to have better understanding of the effects of chlorine exposure on laryngeal and vocal health.

b) In Chemical Laboratories

Hoode, Mathew and Thomas (2019) administered vocal fatigue index in two groups of individuals between the age range of 20 to 25 years in order to understand the self perceived vocal symptoms in those who were exposed to chemicals. They have compared the self perceived vocal fatigue symptoms between two groups to find the effects of chemicals on voice. Group 1 consisted of 42 individuals who were pursuing their Masters degree and were exposed to chemical substances for a period of 3 hours everyday. The chemicals exposed to in the chemical laboratory were HNO3, H2SO4, etc. Group 2 consisted of 40 individuals who had clinically normal voice and who did not have exposure to chemicals previously for a period of 3 years. Individuals who were professional voice users and those with gastro esophageal reflux disease, neurological illness, psychiatric issues or diagnosed to have voice disorders previously were excluded from the study based on which 20 students from both groups were taken up for the study. The vocal fatigue index consists of 19 questions regarding vocal fatigue which needs to be rated on 5 point rating scale ranging from 0 (never) to 4 (always). It was reported by the authors that the individuals of group 1 complained of experiencing vocal dryness and respiratory dryness post exposure to chemicals. Individuals of group 2 had lower scores on the vocal fatigue index as compared to those in group 1. It was inferred that the duration and the amount of exposure to chemicals also play a major role. The major limitations of the study includes the lack of large sample size, exposure to particular chemical agents and lack of acoustic analysis. Hence, future studies may be conducted in order to provide appropriate counselling strategies to those exposed to chemical substances on a daily basis and to consider larger sample sizes and along with performing acoustic analysis.

c) Other Chemicals

Ahlander et al. (2009) evaluated the effects of metacholine challenge test on both vocal function and vocal tract in individuals who were suspected to have nonspecific hyperreactivity. The metacholine testing is most commonly used to evaluate allergy and hyperreactivity testing narrows the respiratory passage after inhalation. Ten participants between the age range of 20 to 60 years who experienced hoarseness in voice due to environmental exposure at workplace were taken up for the study and ten individuals who did not have any voice or hyperreactivity complaints at the time of evaluation were taken up as controls. The participants of the study were made to sniff NaCl on in first occasion and 4ml of methacholine in increasing doses (3, 6, and 12 mg/mL). The subjects underwent three challenge sessions with an interval of 15 minutes in between each. The reading samples of the individuals (standardised Swedish reading passage) were collected using Otari tape recorder during the initial stages and later stages on Sony MDS101 with a microphone. Perceptual evaluation was carried out by 3 speech language pathologist. Visual analogue scales (VAS) was used to evaluate the voice parameters like breathiness, hyperfunction, vocal fry, roughness, increased pitch, aphonic episodes, hard glottal attacks, unstable register, sonority and grade of the disorder. Grade of GRBAS scale used to evaluate the grade of voice. Laryngostroboscopy was performed using 70 degree rigid laryngoscope and the recording was analysed to find the following; pattern of ab–adduction; characteristics, mucosal wave; structure of vocal folds; symmetry/asymmetry in posterior larynx according to protocol of Hirano and Bless (1993). The nasal secretions were collected in a test tube within 15 minutes of exposure. The subjects could also report the subjective symptoms that they faced post exposure. Hoarseness of voice was also reported by 6 individuals after exposure to both NaCl and metacholine. Grade of Voice Disorder was judged higher in patients as compared to controls, already at base recordings. Nasal secretions increased in both groups post exposure to metacholine than NaCl. Subjective complaints were reported in both groups but there was a difference in symptoms reported. The frequency of subjective symptoms were reported to be the same in both groups. The control group reported to have nose symptoms such as stuffed nose and runny nose and the patient group reported to have vocal symptoms and throat symptoms. No significant changes in laryngeal structures and functions were reported in both groups. The exposed subjects also complained about the nose, vocal and throat complaints. Hence, it was concluded from this study that individuals who have hyperreactiveness may become predisposition to develop voice disorders. Cognitive training strategies need to be employed during therapy in order to train these individuals to respond appropriately to various levels of the allergic substance.

CHAPTER III

METHOD

The aim of the present study was to document the effect of chemical substance exposure on parameters of voice such as fundamental frequency, jitter, shimmer and HNR. Also, the study aimed to document the self perceptual rating of vocal tract discomfort symptoms among participants who were exposed to chemical substance by using Vocal Tract Discomfort Scale(VTDS) and compare it with age and gender matched controls.

Participants

The participants consisted of two groups. Group 1 consisted of 18 male participants between the age range of 20 and 40 years who work in a paint manufacturing and application industry which mainly manufactures Epoxy and Polyurethanes. The major chemicals at their occupational environment mainly consisted of Polyol (-OH) and polyisocyanate (-NCO) that react together to give Polyurethane (-NHCOO-). They were also exposed to fumes, dust particles and other irritants. The work schedule consisted of about 7- 8 hours of work with half an hour of lunch break in between for about 6 days a week.

The subjects fulfilling the following criteria were selected for group 1:

1. Within the age range of 20-40 years
2. Have had an exposure to the above mentioned chemicals for a miniumum period of 6 months
3. No voice or swallowing disorders at the time of evaluation

4. No allergic reactions, immunological, neurological, otorhinolarygological, osteomuscular, gastrointenstinal, endocrine and/or psychiatric disorders
5. Have normal hearing screening sensitivity on assessment through informal screening tests

Group 2 consisted of 18 age and gender matched participants who fulfilled the following conditions:

1. Within the age range of 20-40 years
2. Have not had any exposure to chemicals, fumes, toxic substances, harmful gases, organic dust etc
3. No voice or swallowing disorders at the time of evaluation
4. No allergic reactions, immunological, neurological, otorhinolarygological, osteomuscular, gastrointenstinal, endocrine and/or psychiatric disorders
5. Have normal hearing sensitivity on assessment through informal screening tests

To rule out effects of increasing age on parameters of voice the upper age limit was limited to 40 years and to rule out effects of puberty on voice, the lower limit was considered to be 19 years.

Demographic details and a general case history of associated conditions such as hypertension, diabetes, details of previous surgery, psychiatric issues, duration of exposure, type and duration of protective equipment used were all obtained by direct interview.

Material/Instrumentation

The self perceptual vocal complaints were documented using the Vocal Tract Discomfort Scale (VTDS) which was developed by Mathieson (1993). It takes into account sensory symptoms experienced by these individuals with voice disorders or laryngeal pathologies. VTDS includes eight qualitative descriptors regarding the vocal tract which are;

1. Burning sensation of throat
2. Tightness in throat
3. Dryness in throat
4. Ache in throat
5. Tickling sensation in throat
6. Sore throat
7. Irritability in throat
8. Feeling of lump in the throat

The frequency and severity are the two subscales on the above 8 descriptors would be rated on a 7 point rating scale. In the frequency subsection ‘0’ indicates ‘none’; ’2’ indicates sometimes; ’4’ indicates ‘often’ and ‘6’ indicates ‘always’. On the other hand ‘0’ indicates ‘none’; ’2’ indicates ‘mild’; ’4’ indicates ‘moderate’ and ‘6’ indicates ‘extreme’ on the severity subscale.

Objective voice analysis was carried out by using PRAAT (Boersma and Weenink, 1991) software.

Procedure

All the participants were given two tasks in the study.

Task 1-The aim of the study was explained to the individuals before the testing procedure was started**.** Both oral and written consent was obtained from the participants. Copies of the translated (Tamil) VTDS scale was distributed to the participants where they had to rate their perceived vocal symptoms based on frequency and severity of symptoms. The researcher personally helped them with any clarifications by explaining the questions with different examples if they found any difficulty.

Task 2-The acoustic voice measurement was carried out in a relatively noise free room. The participant were seated comfortably in front of the laptop with a directional microphone at a distance of around 10 cm where the recording sampling frequency was kept at 44.1 KHz. The subjects were instructed to phonate vowel /a/ thrice at their habitual pitch and loudness after a deep inhalation for a period of 7-8 seconds. Praat software was used for the recording of the vowel phonation sample. The best of the three trials was taken up for the analysis in which the initial 2 and final 2 seconds of the recording was eliminated taking the remaining for analysis.

Analysis

The scores obtained on the subscales such as ‘frequency’ and ‘severity’ in VTDS were calculated which would range from 0-48 for each of the subscales separately. The summation of these subscales would give the total score which would range from 0-96. Higher scores on the VTDS indicates higher presence of vocal tract discomfort symptoms. The total score obtained for Group 1 and Group 2 was compared to study the effects of exposure to chemical substances on self-perceived vocal symptoms.

The frequency subscale specifically determines the presence or absence of the particular symptom. The cut of values for these symptom in terms of frequency would be 0.5 for burning, tightness, aching, tickling, and sore throat symptoms; 2.5 for dryness, irritation, and lump in the throat symptoms. The values equal to or greater than the cut off indicates the presence of the symptom as defined by Rodrigues et al. (2013). The cut off values for severity would be 0.5 for soreness, tickling, aching and tightness symptoms; 1.5 for burning and lump in throat symptoms; 2.5 for dryness and irritability symptoms as defined by Rodrigues et al. (2013).

The recorded samples of the phonation of vowel /a/ samples were analysed for the following acoustic parameters:

1. Fundamental frequency (F0)
2. Jitter
3. Shimmer
4. Harmonic to noise ratio (HNR)

1. F0 may be defined as the number of vibratory cycles of the vocal folds per second. It is a parameter which is widely used in acoustic to compare intersubject and intrasubject pitch levels. It is one of the first parameters to be affected due to the presence of structural or physiological changes in vocal fold vibratory patterns as said by Tuhanioğlu et al. (2019)
2. In acoustic analysis jitter is a common perturbation measurement. It is the variation of frequency in successive cycles. It can be used to measure frequency instabilities in voice.It can be correlated with the quality of voice in terms of its hoarseness or roughness[Boone et al. (2005); Tuhanioğlu et al. (2019]
3. Shimmer is also a common measurement of perturbation in acoustics. It is the variation amplitude in successive cycles. It is used to measure amplitude instabilities in voice [Boone et al. (2005); Tuhanioğlu et al. (2019]. It can be correlated with the quality of voice in terms of its hoarseness or roughness.

4. Harmonic-noise ratio (HNR) is the ratio of harmonic energy to noise. A higher HNR value indicates better voice quality and periodic properties of voice. It suggests better vibratory patterns of the vocal folds and articulatory functioning [Sidtis et al. (2010); Tuhanioğlu et al. (2019)].

These parameters were compared across both groups to determine the effects of exposure of chemical substances on acoustic voice measures.

Statistical Analysis

The total scores on the perceived sensory vocal symptoms and acoustic voice parameters were tabulated and compared using the SPSS software (version 20.0). Descriptive Statistics was done to obtain mean, median and standard deviation of the scores on Vocal Tract Discomfort Scale (VTDS) and acoustic voice parameters. Normality of the sample was studied using Shapiro-Wilk's Test.

Since the data did not follow normal distribution, Mann Whitney U Test was administered to compare the scores obtained on the VTDS and acoustic voice parameters between the two groups.

In order to compare the frequency and severity of the vocal tract symptoms perceived by participants between the groups Chi Square test of Association was employed. Since the data was lesser than fifty, Chi Square test of Association could not be performed.

Chapter IV

RESULTS

The present study aimed to determine the effects of chemical substance exposure on perceived vocal symptoms using the Vocal Tract Discomfort Scale and on acoustic voice parameters. These values were then compared between group 1 and group 2. The results of the study are described under the following headings;

1. Comparison of total VTDS scores between the two groups
2. Comparison of total scores obtained on the frequency and severity subsections between both the groups
3. Number of symptoms on VTD reported by both the groups
4. Comparison of mean frequency and severity scores on VTDS symptoms between the two groups
5. Comparison of acoustic parameters of voice between the two groups.

1. Comparison of total VTDS scores between the two groups

It can be seen from the table 4.1, group 1 obtained higher mean scores on the VTDS scale as compared to group 2. Higher standard deviation in total scores has been observed in group 1 as compared to group 2.

Table 4.1

Mean, Median and Standard Deviation of the total VTDS scores between both the groups

Total VTDS score	Group 1	Group 2
Median	26.50	8.00
Mean	26.1	7.28
Standard Deviation	9.91	2.69

2. Comparison of the total scores obtained on the frequency and severity subsections of VTDS between both the groups

The sum of scores for each symptom were calculated for each participant from both the groups after which the mean and standard deviation was obtained through descriptive statistics. It can be seen from table 4.2 that group 1 had higher mean and standard deviation on both frequency and severity subsections of VTDS as compared to group 2.

Table 4.2

Mean and standard deviation of the frequency and severity subsections scores of VTDS

Subsections of VDTS	Group 1		Group 2	
	Mean	Standard Deviation	Mean	Standard Deviation
Frequency	12.83	4.10	3.83	1.82
Severity	13.11	4.82	3.67	1.41

Results of Mann Whitney U test revealed higher mean rank scores (27.06) for group 1 for VTDS total score and low mean rank scores (9.94) for group 2 on the VTDS total score. Higher mean rank value indicates higher VTDS total scores for group 1 and lower mean rank value indicates lower VTDS total scores for group 2.

Results of non parametric Mann Whitney U test revealed that there is a significant difference found for the VTDS total scores between the groups (/z/=4.895; $p<0.05$) which indicated that group 1 had significantly higher total scores on VTD scale when compared to group 2.

3. Number of symptoms on VTDS reported by both the groups

Table 4.3

Number of symptoms reported on VTDS scale by both the groups of individuals

Number of symptoms	Group 1	Group 2
0	0	1
1	1	6
2	3	7
3	4	2
4	4	1
5	2	1
6	2	0
7	1	0
8	1	0

Table 4.3 shows the number of participants who reported to perceive particular symptoms on the VTDS scale. Considering presence of 3 or more symptoms to be the cut off value, it can be seen that a majority of the participants from group 1 (77.77%) reported to have 3 or more symptoms. On the other hand, very few participants (22.22%) reported to have 3 or more symptoms in group 2.

4. Comparison of mean frequency and severity scores of VTDS symptoms between the two groups

Frequency Scores

Table 4.4 presents the data collected from the VTDS showing the distribution of frequency scores between both the groups. It can be seen that the mean frequency scores for all participants across all symptoms were higher for group 1 as compared to group 2 except on aching symptom which was found to be similar in both groups. The standard deviation is also noticed to be higher in group 1 as compared to group 2 for all symptoms.

Table 4.4

Mean and standard deviation of mean frequency scores obtained on VTDS scale

Symptom	Group 1		Group 2	
	Mean	Standard Deviation	Mean	Standard deviation
Burning	2.22	1.35	0.33	0.59
Tightness	1.33	1.18	0.33	0.48
Dryness	2.67	0.97	0.56	0.70
Aching	0.94	1.21	0.94	0.87
Tickling	2.28	0.82	0.39	0.69
Soreness	1.22	1.03	0.50	0.78
Irritable	1.78	0.87	0.22	0.54
Lump in throat	0.11	0.47	0.00	0.00

Results of Mann Whitney U test described in table 4.5 revealed higher mean rank scores for group 1 for mean frequency score for symptoms burning, tightness, dryness, tickling, soreness, irritability and lump in throat and low mean rank scores for the same symptoms in group 2. Higher mean rank value indicates higher mean frequency scores for group 1 and lower mean rank value indicates lower mean frequency scores for group 2. The symptom aching has a lower mean rank score in group 1 as compared to group 2 indicating the higher mean frequency scores for aching in group 2.

Table 4.5

Results of Mann Whitney U test for mean frequency subsection score comparison between both the groups

Symptoms		**Group 1**	**Group 2**
Burning	Mean Rank	25.31	11.69
	Sum of ranks	455.00	210.50
Tightness	Mean Rank	22.83	14.17
	Sum of ranks	411.00	255.00
Dryness	Mean Rank	26.83	10.17
	Sum of ranks	483.00	183.00
Aching	Mean Rank	17.97	19.03
	Sum of ranks	323.50	342.50
Tickling	Mean Rank	26.53	10.47

	Sum of ranks	477.50	188.50
Soreness	Mean Rank	21.92	15.08
	Sum of ranks	394.50	271.50
Irritable	Mean Rank	25.75	11.25
	Sum of ranks	463.50	202.50
Lump in throat	Mean Rank	19.00	18
	Sum of ranks	342.00	324.00

Results of non-parametric Mann Whitney U test revealed that there is a significant difference found in mean frequency scores between the groups for the following symptoms:

- Burning (/z/=4.13; $p<0.05$)
- Tightness (/z/=2.71; $p<0.05$)
- Dryness (/z/=4.97; $p<0.05$)
- Tickling (/z/=4.91; $p<0.05$)
- Soreness (/z/=2.18; $p<0.05$)
- Irritable (/z/=4.51; $p<0.05$)

This indicates that there are significantly higher mean frequency scores for group 1 on symptoms burning, tightness, dryness, tickling, soreness and irritability as compared to group 2. There is no significant difference found in mean frequency of VTDS scores between the groups for aching and lump in the throat at a 0.05 significance level.

Severity Scores

Table 4.6

Mean and standard deviation of the mean severity scores obtained on the VTDS

Symptom	Group 1		Group 2	
	Mean	Standard Deviation	Mean	Standard deviation
Burning	2.39	1.50	0.33	0.59
Tightness	1.39	1.14	0.44	0.70
Dryness	2.83	1.09	0.56	0.70
Aching	1.00	1.37	1.00	0.90
Tickling	2.39	1.14	0.33	0.59
Soreness	1.28	0.98	0.83	1.20
Irritable	2.06	1.43	0.28	0.66
Lump in throat	0.11	0.47	0.00	0.00

Table 4.6 presents the data collected from the VTDS scale showing the distribution of severity scores between the groups. It can be seen that the mean severity scores for all participants across all symptoms were higher for group 1 as compared to group 2 except on aching symptom which was found to be similar in both groups. The standard deviation is also noticed to be higher in group 1 as compared to group 2 for all symptoms.

Table 4.7

Results of Mann Whitney U test for the mean severity scores comparison between both the groups

Symptom		Group 1	Group 2
Burning	Mean Rank	25.22	11.78
	Sum of ranks	454.00	212.00
Tightness	Mean Rank	22.72	14.28
	Sum of ranks	409.00	257.00
Dryness	Mean Rank	26.72	10.28
	Sum of ranks	481.00	185.00
Aching	Mean Rank	17.67	19.33
	Sum of ranks	318.00	348.00
Tickling	Mean Rank	26.39	10.61
	Sum of ranks	475.00	191.00
Soreness	Mean Rank	20.83	16.17
	Sum of ranks	375.00	291.00
Irritable	Mean Rank	25.36	11.64
	Sum of ranks	456.50	209.50
Lump in throat	Mean Rank	19.00	18.00
	Sum of ranks	342.00	324.00

Results of Mann Whitney U test described in table 4.7 revealed higher mean rank scores for group 1 for mean severity score for symptoms burning, tightness, dryness, tickling, soreness, irritability and lump in throat and low mean rank scores for the same symptoms in group 2. Higher mean rank value indicates significantly higher mean severity scores for group 1 and lower mean rank value indicates significantly lower mean severity scores for group 2. The symptom aching has a significantly lower mean rank score in group 1 as compared to group 2 indicating the higher mean severity scores for group 2.

Results of non parametric Mann Whitney U test revealed that there is a significant difference found in mean severity scores of VTDS between the groups for the following symptoms:

- Burning (/z/=4.05; $p<0.05$)
- Tightness (/z/=2.63; $p<0.05$)
- Dryness (/z/=4.84; $p<0.05$)
- Tickling (/z/=4.73; $p<0.05$)
- Irritable (/z/=4.22; $p<0.05$)

This indicates that there are significantly higher mean severity scores for group 1 on symptoms burning, tightness, dryness, tickling and irritability as compared to group 2. There is no significant difference found in the mean severity scores between the groups for aching, soreness and lump in the throat symptoms at 0.05 significance level.

5. **Comparison of acoustic parameters of voice between the two groups**

Table 4.8

Mean, Median and Standard Deviation of acoustic parameters between the two groups

Parameters		**Group 1**	**Group 2**
F0 (Hz)	Mean	122.69	129.86
	Median	124.33	129.93
	Standard Deviation	12.67	8.20
Jitter (%)	Mean	0.51	1.60
	Median	0.39	0.66
	Standard Deviation	0.38	1.41
Shimmer (%)	Mean	9.65	11.31
	Median	8.58	11.95
	Standard Deviation	2.79	4.28
HNR	Mean	13.48	8.10
	Median	13.30	8.18
	Standard Deviation	2.58	2.64

Table 4.8 shows the mean, median and standard deviation obtained on the acoustic parameters between the two groups.

1. It can be seen that group 1 had lower mean and median F0 as compared to group 2. Standard deviation of F0 was found to be higher in group 1 as compared to group 2.
2. It can be seen that group 1 had lower mean, median and standard deviation in Jitter values compared to group 2.
3. It can be seen that group 1 had lower mean, median and standard deviation in Shimmer values compared to group 2.
4. It can be seen that group 1 had higher mean and median HNR as compared to group 2. Standard deviation was found to be higher in group 1 as compared to group 2.

Table 4.9

Results of Mann Whitney U test for group comparison on acoustic parameters of voice between the groups

Parameters		**Group 1**	**Group 2**
F0 (Hz)	Mean Rank	15.39	21.61
	Sum of ranks	277.00	389.00
Jitter (%)	Mean Rank	13.28	23.72
	Sum of ranks	239.00	427.00
Shimmer (%)	Mean Rank	17.50	19.50
	Sum of ranks	315.00	351.00
HNR	Mean Rank	26.28	10.72
	Sum of ranks	473.00	193.00

Results of the Mann Whitney U tests in table 4.9 revealed that higher mean rank value was obtained for group 2 in parameters such as F0, Jitter and shimmer as compared to group 1. Higher mean rank value indicates significantly higher F0, jitter and shimmer values in group 2 as compared to group 1. The mean rank value for HNR was found to be higher in group 1 as compared to group 2. This indicates that the HNR values were higher in group 1 as compared to group 2.

Table 4.10

Z and p values obtained through Mann Whitney U test for acoustic parameters of voice between both groups

Parameters	**Z value**	**P value**
F0 (Hz)	1.173	0.076
Jitter (%)	2.977	0.003*
Shimmer (%)	0.570	0.569
HNR	4.431	0.000*

(*indicates significant at 0.05 level)

Results of the Mann Whitney U test as described in table 4.10 revealed that there is a significant difference found for jitter and HNR values between the two groups. The higher values on the HNR parameter in group 1 was found to be statistically significant as compared to group II through Mann Whitney U test ($/Z/=4.43$, $p<0.05$). The lower values on the jitter parameter in group 1 was found to be statistically significant as compared to group 2 through Mann Whitney U test (/Z/=2.977, $p<0.05$). The lower F0 and the lower shimmer were not found to be statistically significant between the groups as p value is greater than 0.05 level of significance.

Summary of findings of the present study were group 1 has got significantly higher total scores on VTDS when compared to group 2. Similarly, the mean frequency and severity scores were found to be higher in group 1 when compared to group 2. Seventy eight percent of the participants in group 1has reported to have had reported of experiencing 3 or more than 3 vocal tract discomfort symptoms when compared to group 2.Goup 1 reported to have experienced the following sensory symptoms of the vocal tract frequently which are dryness, tickling, burning, irritation and tightness whereas aching symptom was the least experienced by them. Sensory symptoms of the vocal tract discomfort as experienced by group 2 frequently was ‘aching’ followed by dryness and soreness of the throat and the least reported symptom was lump in the throat.

Similarly, the sensory vocal tract discomfort symptoms like dryness, tickling and burning sensation in the throat has reported to have higher severity in group 1.On the other hand it was aching and soreness of the throat in group 2.

Acoustic parameters like fundamental frequency (F0),jitter and shimmer values were found to be lower in group 1 when compared to group 2. Harmonic to noise ratio parameter was found to be higher in group 2 as compared to group 1.

CHAPTER V

DISCUSSION

The present study aimed to determine the effects of chemical substance exposure on the self-perceptual rating scale using the Vocal Tract Discomfort Scale and on the acoustic voice parameters. These values were then compared with their age and gender matched controls. The current study has compared 18 individuals who were exposed to chemicals such as polyurethanes and isocyanates in a paint manufacturing industry with other 18 age and gender matched individuals who did not have any voice disorders nor had any exposure to chemicals previously.

The data did not follow normality and hence non parametric tests had to employed to analyze the data.

The results of the present study have revealed several points of interests;

First, the total mean VTDS scores for group 1 was significantly higher (26.10 when compared to group 2 (7.28). Hence, it can be said that higher scores in group 1 indicates higher presence of vocal tract discomfortness as compared to group 2. Higher VTDS scores for group 1 is due to the prolonged continuous exposure to chemical substances such as polyurethanes and isocyanates in their work place.

Perception of vocal tract discomfort symptoms and vocal productions are mutually associated. Higher the perception of vocal symptoms directly relates to the dysfunctional voice. Higher perception of vocal tract discomfortness occur in those individuals who are prone to develop vocal fold lesions or in those with MTD (Darawsheh, Natour and Sada, 2017). Symptoms detected through VTDS may help us predict the vocal health conditions (Darawsheh et al., 2020). It can be predicted from these evidences and the higher scores on the VTD scale in group 1 participants that they are more prone to develop vocal fold lesions leading to voice disorders as compared to group 2.

Generally, it is known that chemicals components which mainly be found in the work environments in the form of gas, fumes, mist, vapour and smoke which cause irritations to the mucuos membrane of the upper respiratory tract (Fabricant, 1963). The presence of changes in the vocal fold layers could also lead to the perception of symptoms which has been validated previously in literature. The vocal fold is made of layers of epithelial cells combined by junction complexes composed of unique interface with the environment which provides structurally stability against irritants and chemicals. Prolonged continuous exposure to chemical substances may cause decrease in the protective functions causing perception of vocal symptoms. The reduced protective functions may in turn produce abnormal vocal fold movement patterns as compared to normals as reported by Hoode, Mathew and Thomas (2019).

Similarly, increased scores in VTDS have been found in various pathological conditions. A study conducted by Darawsheh et al. (2019) found higher VTDS scores were reported in fifteen participants with organic voice disorders and sixteen participants with functional voice disorders as compared to lower scores in 171 healthy controls. Similarly, increased VTDS scores have found to be obtained in individuals with muscle tension dysphonia as compared to their healthy controls (Torabi et al., 2015). Therefore, one may correlate higher VTDS scores obtained for group 1 indicate that they are more vulnerable to develop voice disorders if they continue to get exposed to such chemicals in the long run.

There have been other studies in literature reporting higher scores on other self-perceived evaluation materials like the vocal fatigue index (VHI) in individuals who were exposed to laboratory chemicals as compared to their age and gender matched controls as reported by Hoode, Mathew and Thomas (2019).

There has been a statistically significant difference found on the VTDS total scores between group 1 and group 2. This could be due to exposure to chemicals at their work place for group 1 participants as compared to group 2 who did not have chemical substance exposure. The exposure to chemical substance at work environment for group 1 could act as a predisposing factor for the development of voice problems. This is in accordance with a study previously reported by Mathieson (1993) who concluded that presence of symptoms on the vocal tract discomfort scale do not indicate direct changes in the vocal fold mucosa but may indicate features of voice disorders, or may be due to the involvement of central, or peripheral mechanism of the central nervous system. Even low levels of discomfort scores on VTDS may indicate presence of dysphonia Mathieson (1993).

Second, the mean frequency subsection scores of VTDS for group 1 (12.83) was higher than group 2 (3.83). Also, the mean scores on severity subsection of VTDS for group 1 (13.11) was higher when compared to group 2 (3.67). The increased scores on the subsections frequency and severity were due to continuous exposure to chemical substances like polyurethanes and isocyantes for group 1 as compared to group 2.

Higher scores on the frequency subsection is due to the higher occurrence of vocal tract discomfortness in group 1 as compared to group 2. This can be attributed to the fact that group 2 participants did not have a history of exposure to such chemical substances in a long, and continuous exposure to chemicals as compared to group 1. This is in accordance with previous studies done by Ohlsson et al. (1987) where the vocal complaints were more frequently reported by the non-smoking welder group as compared to the office clerks due to the presence of dust, gases, and fumes in the work environment. Kasbi et al. (2022) reported that the chlorine factory workers reported to have more frequent laryngeal and voice complaints as compared to the non-chlorine factory workers. Geneid et al. (2009) reported that there was perception of acute voice and throat symptoms post exposure to organic dust for a short period of 30 minutes in nine individuals suspected to have occupational rhinitis or asthma. Also, Mesallam et al. (2015) found that 27.8% of participants reported to have laryngeal symptoms post exposure to short duration of fumes released from the burning of incense sticks.

Higher mean severity scores obtained in the subscales of VTDS in group 1 participants can be attributed to the continuous and prolonged exposure to chemicals which probably may cause some structural changes in the vocal folds.

It has also been reported in literature, a higher total scores on the frequency and severity subsections was obtained on VTDS in individuals with MTD (Torabi et al. (2015). Also, Darawsheh et al. (2019) reported higher scores in frequency and severity subscales on VTDS in organic and functional voice disorders.

Third, majority of the participants from group 1 (77.77%) reported to have 3 or more symptoms. On the other hand, very few participants (22.22%) reported to have 3 or more symptoms in group 2. Also, the number of participants who perceived less than 3 symptoms in group 1 was 22% in group 1 and it was 72% in group 2. Due to the exposure of chemical substances in the work place for group 1, more number of symptoms experienced by them when compared to group 2. These sensory discomfort symptoms were aptly captured by VTDS tool in the vocal tract region.

Similar results have been obtained by Mesallam et al. (2015) where 27.8% of participants in that study reported to have laryngeal symptoms owing to the exposure of fumes from the burning of incense sticks for a short duration. In a study by Rodrigues et al. (2013) where they used VTDS to compare the presence of vocal symptoms between teachers with self reported voice problems and teachers without self reported voice problems, it was found that the majority of the teachers with self reported voice problems had 3 or more symptoms on VTDs scale as compared to only very few teachers without self reported voice problems.

The perception of more number of symptoms by most participants in group 1 is similar to the trend observed in teachers with self reported voice problems of Rodrigues et al. (2013) study which indicate the participants in group 1 are more susceptible to voice disorders in future due to chemical substance exposure.

Fourth, both in terms of mean frequency and severity of VTD symptoms, group 1 reported to have more VTD symptoms such as burning, tightness, dryness, tickling, soreness and irritation of throat. Whereas in group 2, aching symptom was predominantly reported as compared to other symptoms present on the VTD scale.

Burning sensation, tightness of the throat, dryness of the throat, tickling sensation, soreness of the throat, irritability of the throat and soreness of throat has higher mean frequency scores in group 1 as compared to group 2. Dryness of throat, soreness of throat, burning sensation of the throat reported are in accordance with previous studies done by Lisboa and Mello (2018) on individuals who were exposed to a wide range of chemical substances. Throat burning and throat dryness are in accordance with previous studies as done by Messalam et al. (2015) while studying the effects on fumes released from the burning of incense sticks on voice. Irritability of the throat was in accordance with previous studies done by Anderson (2015). However, lump in the throat has not been reported by any of the participants in the present study which is not in accordance with previous studies done by Lisboa and Mello (2018) who reported the presence of lump as one of the common symptoms. However, tightness in the throat has been reported by the participants in the present study which is not in accordance with previous studies. The differences in the type of symptoms reported by group 1 when compared with previous studies are due to differences in the study population, and type of chemical substance exposure.

Frequency decides the presence or absence of a particular symptom. Rodrigues et al. (2013) found that there was higher mean frequency scores across all symptoms on the VTDS in teachers with self reported voice problems than in teachers without self reported voice problems. Lopes et al. (2015) also found that there was a higher mean frequency scores on VTDS in individuals who was diagnosed to have pathologies in the membranous parts of the vocal fold and those with gastro esophageal reflux disorder.

The results of the non parametric Mann Whitney U test revealed that there was a statistically significant difference between the mean frequency scores on symptoms burning, tightness, dryness, tickling, soreness and irritability. Mathiesson (1993) has further found a relationship between the type of voice disorder and of the symptoms reported by individuals. Tightness, soreness and lump in the throat are mostly associated with muscle overuse or misuse practises. Tightness, soreness and lump in throat may be due to the overuse of voice in the occupational environment along with the presence of chemical substance exposure. Ohlsson et al. (1987) describes that many factory workers have excessive vocal demands due to the presence of excessive noise in the work environments. The workers usually try to raise their voice and speak thus causing strain and overuse. Tissue damage or inflammatory changes would often cause symptoms like tickling, burning and sore throat as found by Mathiesson (1993).

Further, tightness and soreness symptoms on VTDS by group 1 can be attributed to overuse of voice in the work environment where presence of noise also have an added effect. This would probably lead to the inflammatory changes that usually cause a change in the biomechanics of vocal productions thus resulted in more sensory symptoms.

There is a statistically significant difference between the two groups in the mean severity scores on the symptoms burning, tightness, dryness, tickling and irritability. This may due to the presence prolonged continuous exposure to chemical substances in group 1 as compared to group 2.

On the other hand, the aching symptom was predominantly reported to be more frequent with higher intensities in group 2 participants when compared to group 1. Though the participants involved in group 2 are phono-normals, the higher frequency of aching symptom in them needs to be evaluated further by considering more number of phono-normal participants.

Fifth, group 1 had lower mean fundamental frequency (F0) than group 2. As said by Tuhanioğlu et al. (2019), it is well known that F0 is one of the first parameters to be affected due to the presence of structural or physiological changes in vocal fold vibratory patterns. In the present study, exposure to chemical substances polyurethanes and isocyanates may probably brought a few structural and physiological changes on the vocal folds thus causing decrease in the F0 parameter. It is also seen that there is greater standard deviation in group 1 as compared to group 2 indicating the more heterogeneity in group 1. This could also be due to the fact that there are very few participants who were considered for group 1. Though, the fundamental frequency was found to be less in group 1 compared to group 2, it was not statistically significant difference between the two groups on F0 parameter.

Sixth, the study found a decreased value in jitter and shimmer for group 1 compared to group 2. Jitter and shimmer both are sensitive parameters to measure instabilities in frequency and amplitude due to the variation present in one successive cycle to the next successive cycle (Boone et al., 2005; Tuhanioğlu et al., 2019). These instabilities may be caused due to the changes in vocal fold vibratory patterns due to inhalation of irritants. Due to continuous inhalation of irritants, it would cause few changes in the mucosal wave symmetry or periodicity, glottis closure patterns and mucosal wave quality leading to the changes in the vocal fold vibratory pattern (Gallivan et al., 2007; Nooromplakal et al., 2011). Dogan (2007) reported higher jitter and shimmer values in those who got exposure to chemicals.

The lower F0, jitter and shimmer values indicates a possibility to have an affected phonatory system which may due to exposure to chemical substances. This is in accordance with previous studies done by Nooromplaka et al. (2011) who found lowered F0, jitter and shimmer in individuals who worked in a latex manufacturing company exposed to ammonia. The lower jitter and shimmer values obtained in this study is not in accordance with the study conducted by Messalam et al. (2015) where there was an increase in jitter, shimmer and HNR values post exposure fumes released from the burning of incense sticks for a short period of 5 minutes and Varghese et al. (2019) who found higher jitter and F0 in saw dust workers as compared to normals.

On performing Mann Whitney U test for both jitter and shimmer parameters to analyse between group comparisons, it was found there was a statistically significant difference only for jitter parameter and not for shimmer measure. The results of the present study did not support the earlier findings of Dogan (2007). The differences in the findings of frequency and amplitude perturbation measures of previous study by Messalam et al. (2015) and Varghese et al. (2019) and the present study would be because of differences in chemical substance exposure, number of participants and the instrumentation.

Seventh, higher HNR was obtained in group 1 as compared to group 2. This harmonic to noise measure was not considered as one of the acoustic parameters by previously published studies. A higher HNR value indicates better voice quality and periodic vibratory property of vocal folds. Also, higher HNR suggests better vibratory patterns of the vocal folds and articulatory functioning (Sidtis et al., 2010; Tuhanioğlu et al., 2019). In the present study, there was a higher HNR values obtained for group 2 (non-chemical exposed group) than group 1. The lower HNR value in group 1 may be attributed to the relative presence of environment noise during the time of recording and the inability to control the presence of noise level. The group 2 sample were obtained relatively from noise free environment as compared to group 1. The exact differences between HNR measure between group 1 and 2 warrants further examination by considering proper acquisition/recording of samples for HNR analysis and with more number of participants.

CHAPTER VI

SUMMARY AND CONCLUSION

Pitch, loudness and quality of voice of an individual has to be appropriate for an individual's age, gender, cultural background or geographic location. When a deviancy is noticed in terms of voice quality, pitch and loudness one may suspect the presence of a voice disorder.

An occupational voice disorders are those that develop mainly due to work place environment. Teachers, manufacturing/factory workers, salespersons and singers are the populations who are at a higher risk for developing occupational voice disorders.

Few studies on the various symptoms and characteristics of individuals who was exposed to organic dust, fumes, irritants, chemicals etc., have been reported. Most of these studies documented the symptoms perceived by these individuals after a short acute exposure or when there was prolonged continuous exposure of chemical substances. After the exposure to chemicals, the most commonly reported symptoms were dryness of the throat, irritation in throat and nasal regions, lump in the throat, burning sensation of the throat, shortness of breath, and change in quality of voice. Also, studies reported decreased aerodynamic measures in individuals exposed to chemical substances and changes in acoustic voice parameters such as fundamental frequency, jitter, and shimmer thus causing the voice to be perceived as hoarse or rough.

Chemical substances like polyurethanes and isocyanates which are being used as essential ingredients in paint manufacturing companies. Studies on the effects of such chemicals on voice are scanty in Indian context. The present study made an attempt to determine the effects of chemical substance exposure on voice by considering two outcome variables; one self perceptual rating scale of sensory symptoms using vocal tract discomfort scale (VTDS) and another by using acoustic voice analysis. The study included two group of participants. Group 1 included 18 male participants in the age range of 20 to 40 years who are working in a paint manufacturing industry where they were exposed to polyurethanes and isocyanates. Group 2 included were 18 male participants who are not exposed to such chemical and not employee of that paint manufacturing factory and they were referred as age and gender matched controls.

Participants of the study were asked to rate the frequency and severity of vocal tract sensory symptoms using the VTD scale. Also, they were given another task to sustain the phonation of vowel /a/ for 6 to 8 seconds at comfortable pitch and loudness into a computer. Using PRAAT software, acoustic parameters like fundamental frequency (F0), jitter, shimmer and harmonic to noise ratio (HNR) were measured. The scores obtained on the VTDs scale and acoustic voice parameters were subjected to analysis using SPSS software version 20.0 in order to find differences between the groups.

The results of the present study revealed several points of interest;

1. Group 1 has got significantly higher total scores (26.5) on VTDS when compared to group 2 (8). Similarly, the mean frequency and severity sub-scale scores on VTDS were found to be higher in group 1 than group 2.
2. Seventy-eight percent of the participants in group 1 has reported to have had experiencing 3 or more than 3 vocal tract discomfort symptoms when compared to group 2. Only twenty-two percent of Group 2 participants reported to have experience 3 or more than 3 symptoms in VTDS.
3. Group 1 reported to have the most frequent and severe vocal tract discomfort symptoms dryness, tickling, burning, irritation and tightness whereas aching

symptom was the least experienced by them. Sensory symptoms of the vocal tract discomfort as experienced by group 2 as frequently and severely was ‘aching’ followed by dryness and soreness of the throat and the least reported symptom was lump in the throat.

4. Acoustic parameters like fundamental frequency (F0), jitter and shimmer were found to be lower in group 1 when compared to group 2. Harmonic to noise ratio (HNR) parameter was found to be higher in group 2 as compared to group 1. In general, reduced F0 is due to over-strained vocal folds because of environmental hazards exposure for group 1. Also, the participants of group 1 were informally reported that presence of excessive noise in the work environment. Due to the above reasons, probably the thyro-artenoid muscle would undergone wear-and tear phenomenon where the factor of vocal fatigue would have added upon for lower F0 in group 1 individuals. The obtained lower values in jitter, and shimmer and higher HNR in group 1 needs to be verified with large number of samples as this was unexpected findings of the present study.
5. Interestingly, from the results of the present study, it was found that the self rating scale to document the vocal discomfort, VTDS is relatively better in capturing the subtle changes in voice due to the chemical exposure than the acoustic voice measures.

The present study, concluded that VTDs is a useful scale in evaluating vocal tract discomfort which may lead to an incipient voice disorder in the long run in those individuals who exposed to chemicals. It is important to consider self-perceptual symptoms (like VTDS) in individuals who exposed to chemicals, irritants, fumes etc. in clinical assessment along with routine acoustic voice analysis. Generally, both the tools, subjective and instrumental could help us assess and monitor progress in therapy during the course of management of voice disorders.

Clinical Implications of the present study

- The present study helps clinicians to understand the kind of vocal symptoms caused due to irritants or chemicals such as isocynates. It throws light on the self reported symptoms using VTDS and the total scores and sub-scale scores are higher in individuals who have been exposed. Thus it can be included in the clinical assessment of voice along with other routine evaluations.
- The acoustic voice analysis is considered to be simple and accurate where it did not fetch differences in the groups studied in the present study. This warrants further by considering more sensitive acoustic measures along with more participants.
- VTDS helps to monitor changes in voice in individuals who are exposed to irritants for prolonged and continuous periods of time.
- It helps clinicians understand the importance of counselling, inculcating vocal hygiene practices, promoting the use of protective equipment during working hours in individuals who exposed to chemical substances.

Limitations of the present study

- The study has included only a limited number of participants and has considered only males
- It lacks control of extraneous variables like noise.
- Present study considered only limited acoustical voice measures.
- It has documented the effect of only few chemicals.

Future Directions

- The study can be replicated by considering more number of participants including both males and females who have been exposed to a wider range of chemicals.
- Comparisons between other self perceptual rating scales can be made.
- Other methods like direct laryngoscopy, auditory-perceptual assessment of voice can also be considered.
- Factors like age, duration of exposure, usage of voice in work atmosphere can also be considered which may have effects on voice parameters.

REFERENCES

Åhlander, V. L., Malm, L., & Schalén, L. (2009). Hoarseness as a sign of possible nonspecific mucosal hyperreactivity in vocal tract. *Journal of Voice*, *23*(6), 707-715.

Allan, P. F., Abouchahine, S., Harvis, L., & Morris, M. J. (2006). Progressive vocal cord dysfunction subsequent to a chlorine gas exposure. *Journal of Voice*, *20*(2), 291-296.

Anderson, J. A. (2015). Work-associated irritable larynx syndrome. *Current Opinion in Allergy and Clinical Immunology*, *15*(2), 150-155.

Aronson, E. (2009). Clinical voice disorders. Thieme, 2009 - Medical – 301.

Boone, D. R., McFarlane, S. C., Von Berg, S. L., & Zraick, R. I. (2005). The voice and voice therapy.

Brooks SM., Weiss MA., & Bernstein IL. (1985). Reactive airways dysfunction syndrome (RADS). Persistent asthma syndrome after high level irritant exposures. Chest 88, 376–84.

Bucher, J. R. (1987). Methyl isocyanate: a review of health effects research since Bhopal. *Fundamental and applied toxicology*, *9*(3), 367-379.

Darawsheh, W. B., Natour, Y. S., & Sada, E. G. (2018). Applicability of the Arabic version of Vocal Tract Discomfort Scale (VTDS) with student singers as professional voice users. *Logopedics Phoniatrics Vocology*, *43*(2), 80-91.

Darawsheh, W. B., Shdaifat, A., & Natour, Y. S. (2020). Validation of the Arabic version of vocal tract discomfort scale. *Logopedics Phoniatrics Vocology*, *45*(2), 82-90.

Dogan, M., Eryuksel, E., Kocak, I., Celikel, T., & Sehitoglu, M. A. (2007). Subjective and objective evaluation of voice quality in patients with asthma. *Journal of Voice*, *21*(2), 224-230.

Gallivan, G. J., Gallivan, K. H., & Gallivan, H. K. (2007). Inhaled corticosteroids: hazardous effects on voice—an update. *Journal of Voice*, *21*(1), 101-111.

Geneid, A., Rönkkö, M., Airaksinen, L., Voutilainen, R., Toskala, E., Alku, P., & Vilkman, E. (2009). Pilot study on acute voice and throat symptoms related to exposure to organic dust: preliminary findings from a provocation test. *Logopedics Phoniatrics Vocology*, *34*(2), 67-72.

Hannu, T., Piipari, R., & Toskala, E. (2006). Immediate hypersensitivity type of occupational laryngitis in a welder exposed to welding fumes of stainless steel. *American Journal of Industrial Medicine*, *49*(5), 402-405.

Hannu, T., Riihimäki, V., & Pirilä, P. (2009). Reactive airway dysfunction syndrome (RADS) in a chemistry teacher induced by fumes of mixed iodine compounds. *Industrial Health*, *47*(6), 681-684.

Herrington-Hall, B. L., Lee, L., Stemple, J. C., Niemi, K. R., & McHone, M. M. (1988). Description of laryngeal pathologies by age, sex, and occupation in a treatment-seeking sample. *Journal of Speech and Hearing Disorders*, *53*(1), 57-64.

Hillenbrand, J. M. (2011). Acoustic analysis of voice: a tutorial. *Perspectives on Speech Science and Orofacial Disorders*, *21*(2), 31-43.

Hirano M & Bless D. (1993). Videostroboscopic examination of the larynx. San Diego, CA: Singular Publishing Group.

Hoode, A., Mathew, L., & Thomas, A. A. (2019). Vocal fatigue inventory measures in individuals exposed to laboratory chemicals. *Lang India*, *19*, 12-20.

Heydari, F., & Ghanei, M. (2011). Effects of exposure to sulfur mustard on speech aerodynamics. *Journal of Communication Disorders*, *44*(3), 331-335.

Hytönen, M., & Sala, E. (1996). Nasal provocation test in the diagnostics of occupational allergic rhinitis. *Rhinology*, *34*(2), 86-90.

Jardim, R., Barreto, S. M., & Assunção, A. Á. (2007). Voice disorder: case definition and prevalence in teachers. *Revista Brasileira de Epidemiologia*, *10*(4), 625-636.

Jazem F., Ebrahimi A., & Moshtahar Z. (2017). Voice Problems and Risk Factors Reaalted to it among the Females working in the Grade One Hair and Beauty Salon.Semnan:Semnan University of Medical Sciences.

Kasbi, F., Tohidast, S. A., Mansuri, B., Parvizian, Z., Ghorbani, R., Monshizadeh, L., & Scherer, R. C. (2022). Laryngeal and voice symptoms of workers in a chlorine chemical factory. *Journal of Voice* (In press).

Lisbôa, 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*, 209-217.

Lopes, L. W., Cabral, G. F., & de Almeida, A. A. F. (2015). Vocal tract discomfort symptoms in patients with different voice disorders. *Journal of Voice*, *29*(3), 317-323.

Mathieson, L. (1993). Vocal tract discomfort in hyperfunctional dysphonia. *J Voice*, *2*, 40-48.

Mesallam, T. A., Farahat, M., Shoeib, R., Alharethy, S., Alshahwan, A., Murry, T., & Malki, K. H. (2015). Acute effects of inhaling Oud incense on voice of Saudi adults. *Annals of Saudi Medicine*, *35*(2), 111-119.

Nooromplakal, G., Thomas, J., Ganesh, A. C., & Subba Rao, T. A. (2011). Effects of chemical irritants on voice and subsystems-an acoustic analysis. *Journal of the All India Institute of Speech & Hearing*, *30(1), 42-45*.

Ohlsson, A. C. (1983). Voice Problems and Occupational Environment. *Working papers/Lund University, Department of Linguistics and Phonetics*, *25*.

Ohlsson, A. C., Järvholm, B., Löfqvist, A., Näslund, P. E., & Stenborg, R. (1987). Vocal behaviour in welders–a preliminary study. *Folia Phoniatrica et Logopaedica*, *39*(2), 98-103.

Przysiezny, P. E., & Przysiezny, L. T. S. (2015). Work-related voice disorder. *Brazilian Journal of Otorhinolaryngology*, *81*, 202-211.

Ramroth, H., Dietz, A., Ahrens, W., & Becher, H. (2008). Occupational wood dust exposure and the risk of laryngeal cancer: A population based case-control study in Germany. *American Journal of Industrial Medicine*, *51*(9), 648-655.

Rodrigues, G., Zambon, F., Mathieson, L., & Behlau, M. (2013). Vocal tract discomfort in teachers: its relationship to self-reported voice disorders. *Journal of Voice*, *27*(4), 473-480.

Roth, D., & Ferguson, B. J. (2010). Vocal allergy: recent advances in understanding the role of allergy in dysphonia. *Current Opinion in Otolaryngology & Head and Neck Surgery*, *18*(3), 176-181.

Roto, P., & Sala, E. (1996). Occupational laryngitis caused by formaldehyde: a case report. *American Journal of Industrial Medicine*, *29*(3), 275-277.

Smith, S. L., Van Demark, P. J., & Fabricant, J. (1963). Respiratory pathways in The mycoplasma I: Lactate Oxidation by Mycoplasma Gallisepticum. *Journal of Bacteriology*, *86*(5), 893-897.

Sidtis, D. V. L., Rogers, T., Godier, V., Tagliati, M., & Sidtis, J. J. (2010). Voice and fluency changes as a function of speech task and deep brain stimulation.

Tanturri, G., Pia, F., & Benzi, M. (1988). A case of edematous pharyngolaryngitis in a man occupationally exposed to inhalation of Freon gas. *La medicina del lavoro*, *79*(3), 219-222.

Torabi, H., Khoddami, S. M., Ansari, N. N., & Dabirmoghaddam, P. (2016). The Vocal Tract Discomfort Scale: validity and reliability of the Persian version in the assessment of patients with muscle tension dysphonia. *Journal of Voice*, *30*(6), 711-716.

Tuhanioğlu, B., Erkan, S. O., Özdaş, T., Derici, Ç., Tüzün, K., & Şenkal, Ö. A. (2019). The effect of electronic cigarettes on voice quality. *Journal of Voice*, *33*(5), 811-e13.

Uloza, V., Vegienė, A., & Šaferis, V. (2013). Correlation between the basic video laryngostroboscopic parameters and multidimensional voice measurements. *Journal of Voice, 27*(6), 744-752.

Verschoor, L., & Verschoor, A. H. (2014). Nonoccupational and occupational exposure to isocyanates. *Current Opinion in Pulmonary Medicine*, *20*(2), 199-204.