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RESEARCH ARTICLE

A RETROSPECTIVE STUDY: HEARING IMPAIRMENT AND CONTRIBUTING FACTORS AMONG MANUFACTURING FACTORY WORKERS.

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Abstract

Noise is an important occupational health hazard, with a high prevalence in the manufacturing industry. Exposure to excessive noise can pose a risk to human health. Most commonly and of greatest interest, exposure to excessive noise may result in permanent damage to hearing. The aim of this study is to evaluate the determining factors of hearing impairment in manufacturing factory workers. Unmatched case control study was carried out among manufacturing factory workers at "XYZ" Company Qatar. Respondents consisted of 19 cases that were diagnosed from 2013 to 2018 with 176 controls from the same work place. Multivariate analysis was used to determine the association between hearing impairment and the contributing risks being studied. The results of partial logistic regression analysis showed aging ($p < 0.05$), noise dose exposure ($p < 0.05$) and infrequent use of HPD ($p < 0.05$) associated to hearing impairment incident significantly. Service duration ($p > 0.05$), hypercholesterolemia ($p > 0.05$), smoking ($p > 0.05$), diabetes ($p > 0.05$), and hypertension ($p > 0.05$) were not associated to the hearing impairment. Odd Ratio of noise dose exposure to hearing impairment Exp(B) 11.8 (95% CI: 2.498-56.043), infrequent use of HPD Exp(B) 7.3 (95% CI: 2.366-22.585), and aging Exp(B) 1.121 (95% CI: 1.023-1.228). In this study the author concludes that the noise dose exposure was strongest predictor to hearing impairment rather than infrequent use of HPD and aging factor.

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Introduction:-

According to the U.S. Bureau of Labor Statistics, occupational hearing impairment is the most commonly recorded occupational illness in manufacturing (17,700 cases out of 59,100 cases), accounting for 1 in 9 recordable illnesses. More than 72% of these occur among workers in manufacturing ⁽¹⁾. Approximately 22 million U.S. workers are exposed to hazardous occupational noise ⁽²⁾. CDC compared the prevalence of hearing impairment within nine U.S. industry sectors using 1,413,789 noise-exposed worker audiograms from CDC's National Institute for Occupational Safety and Health (NIOSH) Occupational Hearing impairment Surveillance Project ⁽³⁾. CDC estimated the prevalence at six hearing impairment levels, measured in the better ear, and the impact on quality of life expressed as annual disability-adjusted life years (DALYs), as defined by the 2013 Global Burden of Disease (GBD) Study ⁽⁴⁾. The mining sector had the highest prevalence of workers with any hearing impairment, and with moderate or worse impairment, followed by the construction and manufacturing sectors. The NIOSH-1997 model estimates that the risk

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of suffering hearing impairment was 4.3 (95% CI 1.3-9.4) when person exposed to daily noise at 85 dB(A), having worked for more than 10 years and aged 40 years old ⁽⁵⁾.

Among all industries, 13% of noise-exposed workers had hearing impairment and 2% had moderate or worse impairment. Workers with hearing impairment were represented in all industry sectors, with sharply decreasing numbers of workers with higher levels of impairment. The mining sector had the highest prevalence of workers with any impairment (17%) and with moderate or worse impairment (3%), followed by the construction sector (any impairment = 16%, moderate or worse impairment = 3%), and the manufacturing sector (14% and 2%). The public safety sector, which includes police protection, fire protection (including wildland firefighters), corrections, and ambulance services, had the lowest prevalence of workers with any impairment (7%) ⁽⁶⁾.

The contributing factors of hearing impairment were categorized into occupational noise exposure, non-occupational noise exposure (such as free time noise exposure and firearm activities), individual susceptibility such as socio-demography (age, gender, and job title), smoking habit, medical problems (hypertension, diabetes mellitus, hypercholesterolemia, and infections), ototoxic drugs, compliance to hearing protection device (HPD) usage ⁽⁷⁾. Few studies have found that smoking habits, education levels, noisy entertainments, firearm activities, ototoxic drugs, medical problems, and HPD usage have contributed to hearing impairment ^{(8) (9)}.

Hearing impairment as a result of exposure to noise is one of the most frequent pathologies found in workers, and is influenced by a number of parameters, such as intensity of the noise, temporal and spectral patterns, duration of the exposure and susceptibility factors. Controlling these parameters may improve the individual response to noise and evolution of the damage. One of the factors influencing hearing susceptibility which has attracted growing interest in recent years is cigarette smoking, although the role of smoking in abetting the development of sensory neural hearing impairment is controversial, as recent literature shows. Some authors highlight that smokers have a greater risk of hearing impairment than non-smokers ⁽¹⁰⁾, while others find no connection between the onset of sensory neural hearing impairment and cigarette smoking ⁽¹¹⁾. Nomura in a reviewed referring to the period 1966-2003, mentions nine studies which report a positive association between smoking and hearing impairment, and six studies which reach completely opposite conclusions. The author, however, concludes by supporting the thesis of a positive association between smoking and hearing impairment ⁽¹²⁾.

Several studies have demonstrated a relationship between hyperlipidemia and hearing disturbance ^{(13) (14)}. Although, some studies have reported that levels of triglycerides and cholesterol were not consistently related to hearing disturbance, these studies nevertheless attested to the relevance of low-versus high-density lipoprotein ^{(15) (16)}. The association of hearing impairment with Diabetes Mellitus (DM) however, is still controversial. Several studies have shown no or little association between DM and hearing impairment ^{(17) (18)} and a cohort study reported that DM was associated with the development of bilateral hearing impairment ⁽¹⁹⁾.

Hearing impairment is one of the most prevalent chronic conditions in adults worldwide ⁽²⁰⁾ and it is classified as conductive, sensorineural or mixed in type. Conductive hearing impairment has readily identifiable causes and is easily amenable to treatment but sensorineural hearing impairment has more grievous consequences on the individual. Good hearing function is particularly required for adults in the working population who are exposed to noise and other challenging listening situations at work. Because hearing impairment due to noise is irreversible, early detection and intervention is critical to prevention of this condition. Ensure baseline audiograms are obtained for new hires and or employees newly identified as working within a noise-laden environment. A 10-dB confirmed threshold shift from baseline in pure-tone average at 2000, 3000, and 4000 Hz (OSHA standard threshold shift or STS), while not necessarily resulting in significant impairment, is an important early indicator of permanent hearing impairment ⁽²¹⁾.

The “XYZ” company is one of manufacturing industries located in Qatar. Noise level measurements were undertaken in December 2018 by Environment department of “XYZ” Company in the selected areas, using a calibrated direct reading instrument, “EXTECH sound level meter - 407736”, to identify work areas where employees exposures may be above hazardous levels and where a deep/thorough exposure monitoring may be required. A number of representative readings were undertaken in different points surrounding area / vessel which might contribute to environmental noise. The meter was set to the “A” scale (which corresponds most closely to the response of the human ear), and slow response mode, for environment noise. The maximum noise level measured in the plant was 113.5 dB and the minimum reading was 79.4 dB. As part of their hearing conservation program,

periodic audiometric testing was conducted to 302 employees who exposed to noise environment annually by the certified and qualified technician at occupational health clinic of “XYZ” Company. The latest report in 2018 found some cases of hearing impairment 7.6 % among the workers.

Based on the description above, the author is interested in researching the contributing factors of hearing impairment in manufacturing factory at “XYZ” Company Qatar. The aim of the study is to evaluate the contributing factors of hearing impairment in manufacturing industry.

Methods:-

Type of the research used quantitative observational analytics with retrospective case control approach. The manufacturing factory was selected on the basis of incidence of hearing impairment and to assist the factory in optimizing their hearing conservation program. The dependent variable was hearing impairment and the independent variables were aging, service duration, hearing protection device use, smoking status, medical history of hypertension, hypercholesterolemia, and diabetes mellitus.

The research was conducted at Manufacturing Factory in Qatar from March 2019 to July 2019. Nineteen workers with sensorineural hearing impairment were studied retrospectively. The inclusion criteria consisted of workers working in the noise area, consisted of workers aged 30-60 years with a mean loss of more than 25 dBHL averages between the four frequencies 0.5 kHz, 1 kHz, 2 kHz and 4kHz⁽²²⁾, free of ear infections or trauma or surgery, have been working for more than 5 years, no previous occupational history of noisy jobs and agree to participate. Exclusion criteria comprised a history suggestive of a congenital hearing impairment maternal rubella, kernicterus, meningitis, syphilis, head injury or ototoxic drugs. Other exclusion criteria were if they had abnormal syphilis serology, auto anti bodies or thyroid function tests (two subjects) although there is no consistent evidence that hypothyroidism is associated with hearing impairment this was excluded as a possible confounding variable. The control group (N = 176) was recruited from workers who have been working in same company and willingness to participate.

The data consist of primary data and secondary data. Primary data obtained through questionnaire and interview while secondary data obtained through medical records. Throughout the survey, the methods used included a Pure Tone Audiometric (PTA) test, a questionnaire, a personal dosimeter report, recent fasting blood sugar report, blood pressure report and cholesterol results. The audiometry machine was approved and calibrated conforming to the standard requirement by the regulation body in the country. The audiometric tests were conducted in the factory clinic. The audiometric tests were conducted by trained qualified technician after otoscopy examination by doctor. Hearing thresholds were measured in sound-treated booths by pure-tone air (0.5, 1, 2, 3, 4, 6, 8 kHz) and bone conduction (0.5, 2, 4 kHz) audiometry using a modified Hughson-Westlake procedure according to the guidelines of the American Speech-Language-Hearing Association.⁽²³⁾ Masking was used as necessary. The presence of hearing impairment was defined as a pure-tone average (PTA) of thresholds at 0.5, 1, 2, and 4 kHz greater than 25 dB hearing level in either ear. A second definition of PTA greater than 25 dB hearing level in the better ear was also used to capture bilateral hearing impairment. This 4-frequency average has long been used as a measure of hearing impairment in epidemiologic studies⁽²⁴⁾. The annual audiogram was screened to determine hearing impairment by looking into the latest audiogram results, and repeated PTA tests were done for confirmation. The PTA tests were performed after 14 hours free from end of work shifts. The self-administered questionnaire sessions were conducted in the factory's clinic with the presence of the investigator.

The report of personal dosimeter at same work places was conducted in 2018 by registered industrial hygienist in the company. Cirrus CR:110A dosimeter was used with standard ANSI S1.25 and was calibrated frequently. The list of daily personal noise dose in different job titles and work locations was tabulated. These findings were used to determine daily noise dose exposure subjects by questioning their job title and work location since joining this factory. Based on the noise exposure recommendations from NIOSH, the 100% daily noise dose means subjects who work in 8 hours per day equivalent to 90 dB(A), whereas subjects who work in 12 hour shifts per day was adjusted equivalent to 87 dB(A) (5). Meanwhile OSHA recommends the daily noise dose exposure 85 dB (A) TWA 8 hours per day⁽²⁵⁾.

Fasting blood sugar, cholesterol and blood pressure results were based on existing medical records and were reanalyzed by an accredited laboratory in early 2019 as part of their healthy life style program. Diabetes mellitus was defined as a fasting plasma glucose level of 126 mg/dL or greater (to convert to millimoles per liter, multiply by

0.0555), 2-hour postload plasma glucose level of 200 mg/dL or greater, a hemoglobin A_{1c} of 6.5% or greater, self-report of doctor-diagnosed diabetes (excluding gestational diabetes), or use of anti-hyperglycemic medications⁽²⁶⁾.

Dyslipidemia was diagnosed according to National Cholesterol Education Program ATP III criteria⁽²⁷⁾ and defined as TC >200mg/dL, LDL-C > 160mg/dL, HDL-C 150mg/dL. Hypertension was defined as a systolic blood pressure of 140 mm Hg or greater, diastolic blood pressure of 90 mm Hg or greater, or receipt of antihypertensive medication.^{(28) (29)} The items surveyed included the following: 1) socio-demographic data (age, and job title), 2) occupational noise exposure (daily noise dose and service duration), 3) Hearing Protection Device/HPD (Frequency of usage), 5) smoking status, 6) medical condition (hypertension, Diabetes Mellitus, and hypercholesterolemia).

Data were statistically analyzed using SPSS version 25.0 software package. Partial logistic regression analysis was used to determine the association between independent variables and dependent variable. The significance of the result was set at $p < 0.05$. Logistic regression analysis was performed to determine odd ratio and 95% confidence interval (CI). Descriptive analysis also used to analyze data by frequency, mean and distribution of the respondents.

Results:-

Table 1.1 showed, Total participant were 195, consisting 19 (9.7%) cases and 176 (90.3%) controls. Univariate analysis results found the age of case group were a little over 3.8 years older on average than the age of control group. The cases had an average 47.1 years and the controls had an average of 43.3 years. The age of case group had a standard deviation of 5.7 years whereas the controls age data had a standard deviation 6.1. The control data having a higher standard deviation tells us that the age of control group data was more spread out or dispersed than the data from the case. The jobs of the respondent were mostly as an operator. The respondents from the case worked as an operator 89.5% and 10.5% worked as a technician.

The mean daily noise exposure of cases data was 87.7 dB(A) whereas the mean control data was 85.0 dBA It means the average of the noise exposure of the case group was higher 2.7 dB(A) exposed to the noise than the control group. The prevalence of case group with high cholesterol was 31%.6 and the control group was 29.0%. From the descriptive analysis also shown the case group was mostly nonsmokers 94.7%, as well as the control group was 87.5%. The DM prevalence was 89.5% in the case group and 89.8% was in the control group. It showed the prevalence of DM between case and control was almost similar. The participant who had history of hypertension was 94.7% in case group and 98.3% in control group. Infrequent hearing protection device (HPD) usage was 68.4% among case group and 29.0% among the control group. The result demonstrated that infrequent use of HPD in case group was higher than in control group.

Tabel 1.1:-Demographic and hearing impairment risk factors, by subject group

Characteristic	Case (N=19)	Control (N=176)
Age, yrs (mean \pm SD)	47.1 \pm 5.7	43.3 \pm 6.1
Service duration, yrs (mean \pm SD)	14.9 \pm 4.9	14.1 \pm 4.8
Job title		
Operator (%)	89.5	88.6
Technician (%)	10.5	11.4
Cholesterol		
Normal (%)	68.4	71.0
High (%)	31.6	29.0
Smoking		
Nonsmoker (%)	94.7	87.5
Smoker (%)	5.3	12.5
Diabetes mellitus		
Non diabetes mellitus (%)	89.5	89.8
Diabetes mellitus (%)	10.5	10.2
Hypertension		
Non hypertension (%)	94.7	98.3
Hypertension (%)	5.3	7.39
Noise dose exposure, dBA (mean \pm SD)	87.7 \pm 4.2	85.0 \pm 4.0
HPD		

Always use HPD (%)	31.6	71.0
Infrequent use of HPD (%)	68.4	29.0

Table 1.2 showed logistic regression enter method analysis result, age ($p < 0.05$), noise dose exposure ($p < 0.05$) and not all the times used HPD ($p < 0.05$) associated to hearing impairment incident. Factors Service duration ($p > 0.05$), hypercholesterolemia ($p > 0.05$), smoking ($p > 0.05$), diabetes ($p > 0.05$), and hypertension ($p > 0.05$) were not associated to the hearing impairment.

Table 1.2:-Partial Logistic Regression Analysis

Variable	B	Sig.	Exp(B)	95% C.I. for EXP(B)		Remarks
				Lower	Upper	
Aging	1.536	.049	4.644	1.005	21.469	Significant
Service duration	-.187	.830	.829	.151	4.567	Insignificant
Hypercholesterolemia	.453	.610	1.573	.276	8.956	Insignificant
Smoking	-1.244	.302	.288	.027	3.063	Insignificant
Diabetes Mellitus	-.031	.973	.969	.158	5.939	Insignificant
Hypertension	-1.744	.161	.175	.015	2.003	Insignificant
Noise dose exposure	2.793	.001	16.326	3.257	81.847	Significant
Infrequent use of HPD	2.137	.001	8.476	2.451	29.314	Significant
Constant	-6.298	.000	.002			

From table 1.3, Odd Ratio of Noise dose exposure to hearing impairment Exp(B) 11.8 (95% CI: 2.498-56.043), infrequent use of HPD Exp(B) 7.3 (95% CI: 2.366-22.585), and aging Exp(B) 1.121 (95% CI: 1.023-1.228). Based on the result above, we can conclude that the noise dose exposure was highest factor associated to hearing impairment rather than wearing HPD and employee age.

Table 1.3:-Logistic Regression Analysis

Variable	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
Noise dose exposure	2.471	.794	9.696	1	.002	11.833	2.498	56.043
Infrequent use of HPD	1.989	.575	11.949	1	.001	7.311	2.366	22.585
Aging	.114	.047	5.966	1	.015	1.121	1.023	1.228
Constant	-10.115	2.419	17.483	1	.000	.000		

Table 1.4 showed, prediction analysis with Nagelkerke R^2 : 0.335. Noise dose exposure, infrequent use of HPD and age predicted influence of hearing impairment 33.5%. 66.5% influenced by other factors which not describe above.

Table 1.4:-Logistic Regression Analysis

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	90.961 ^a	.158	.335

a. Estimation terminated at iteration number 7 because parameter estimates changed by less than .001.

Discussion:-

The research design was case control which hearing impairment sample as the case and the control was other workers who worked at same exposure within the company. The dependent variable was hearing impairment and the independent variables were aging, service duration, noise dose exposure, HPD usage, smoking status and medical condition (hypertension, diabetes mellitus, and hypercholesterolemia). The case control study design was used in this study which suitable for the rare disease related to hearing on the industrial workers and chronic medical problem in workers exposed to noise. The advantage of this research design is less costly and shorter in duration compared to prospective cohort study. The limitation of this research is study population, which only depends on respondents who were still working. Case control research mainly in this study relying on medical records at company clinic. The accuracy of this medical data depends on the registrar, medical devices, data completeness, and

possibilities lost medical data. Medical check-up data (pre-employment and periodic medical check-up) did not exist or incomplete, especially data before 2015.

The 19 case of hearing impairment in the manufacturing factory at “XYZ” Company is associated with noise dose exposure, infrequent use of HPD and aging factor. These variables predicted influence of hearing impairment 33.5%. Meanwhile 66.5% influenced by other factors which not described in this study. Noise dose exposure OR 11.833 (95% CI: 2.366-22.585) factor was the strongest contribution of hearing impairment in this study. This finding are consistent with report of Rachiotis⁽³⁰⁾ findings indicate that electro production workers were occupationally exposed to high levels of noise, and present high rates of noise-induced hearing impairment (NIHL). Hearing impairment due to continuous or intermittent noise exposure increases most rapidly during the first 10 to 15 years of exposure, and the rate of hearing impairment then decelerates as the hearing threshold increases. This is in contrast to age-related loss, which accelerates over time⁽³¹⁾. This result was in line with many studies result which noise exposure is one of hearing impairment contributing factors⁽³²⁾. There are a number of other causes of sensorineural hearing impairment besides occupational noise. Of primary concern is non-occupational noise exposure from a variety of sources, especially recreational noise, such as loud music, weapons firing, motor sports, etc. Other causes include a wide variety of genetic disorders, infectious diseases (eg, labyrinthitis, measles, mumps, syphilis), pharmacologic agents (eg, aminoglycosides, diuretics, salicylates, antineoplastic agents), head injury, therapeutic radiation exposure, neurologic disorders (eg, multiple sclerosis), cerebral vascular disorders, immune disorders, bone (eg, Paget disease), central nervous system neoplasms, and Menière's disease. A medical history can help in determining whether any of these conditions could contribute to an individual's hearing impairment⁽³³⁾.

Aging is well-known as contributing factor of hearing impairment; the result of our study was consistent in this regard as shown OR 1.121 (CI 95%, 1.023-1.228). The average age of case group was 47.1 years old and the average age of control group was 43.3 years old. So we can conclude the risk of hearing impairment increasing by aging factor. Davis found that in under 45 years old there was not much hearing impairment and mild hearing impairment increases to 1 in 3 of the population for 55-64 years old⁽³⁴⁾. Other study also reported that increasing age was associated with hearing impairment across all frequency definitions of PTA but with greater hearing impairment changes seen at the higher frequencies⁽³⁵⁾.

As per result of regression analysis showed a positive association of hearing impairment and infrequent use of HPD with OR 7.3 (95% CI: 2.366-22.585) in this study. Only 31.6% of the employees exposed to noise always wore hearing protection device at work, meaning that 68.4% of the case group state was not wearing hearing protection device all the time. A study by Starck et al. found that paper and pulp factory workers who wore HPD for 50% of the required duration showed more hearing loss⁽³⁶⁾. Bauer et al, also found a positive association between of the usage of HPDs and hearing impairment by analyzing a very large population of workers exposed to occupational noise⁽³⁷⁾. A study to understand factors influencing the use of hearing protection identified that interpersonal support, barriers, and situational influences as statistically significant predictors of low use of hearing protection device.⁽³⁸⁾ Real world attenuation provided by hearing protective devices may vary widely between individuals. The noise-reduction rating of hearing protective devices used by a working population is expected to be less than the laboratory-derived rating⁽³⁹⁾⁽⁴⁰⁾. Hearing protective devices should provide adequate attenuation to reduce noise exposure at the eardrum to less than 85 dB time-weighted average. In addition, technology is now available, which can provide an individualized attenuation rating for hearing protective devices and continuous monitoring of noise at the eardrum⁽⁴¹⁾⁽⁴²⁾.

Conclusion:-

This study has shown consistent evidence to indicate that aging, infrequent use of HPD and noise dose exposures were contributing factors in hearing impairment. The strongest contributor of hearing impairment was noise dose exposure. Meanwhile service duration, hypercholesterolemia, hypertension, diabetes mellitus and smoking were not associated with hearing impairment.

Hearing impairment prevention, and early detection and intervention to avoid additional hearing impairment, are critical to preserve worker quality of life. Elimination of the hazard is the ideal standard. For example, when plant machinery is replaced, the noise output should be considered in the contract specifications. With machinery and equipment that cannot be submitted the maintenance schedule should be considered because poorly maintained equipment tends to be noisy. It is vital that all workers who exposed to the noise are educated adequately to encourage them to wear hearing protective device. Occupational hearing impairment is preventable through a

hierarchy of controls, which prioritize the use of engineering controls over administrative controls and personal protective equipment. NIOSH recommends re-survey for the noise at work every two years⁽⁵⁾, while OSHA only requires re-survey when conditions change for the worse⁽²⁵⁾. By conducting regular surveys using similar protocols, trends and comparisons can be drawn. These have proven to be useful communication tools to assist in driving hearing loss prevention program decisions.⁽⁴³⁾ Further research needs to be done to analyze others factors may contribute to hearing impairment.

Competing Interests

Authors have declared that no competing interests exist. These products used for this research are commonly and predominantly use product in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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