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Impact of Various Symptoms of Carpal Tunnel Syndrome in Vehicle and Axle Assembly Line in Industry

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Abstract— For localized vibration exposure of the hand and arm to occur, the hand must grip a vibrating object. The effects of vibration in hand intensive work, along with factors, such as forceful and repeated exertion and certain postures. Vibration has been cited as a factor tendon disorders such as Carpal Tunnel Syndrome (CTS) and tendinitis. Vibration may increase the risk of chronic tendon and nerve disorders by increasing the force exerted in repetitive manual tasks. In this study, the survey has been conducted on 69 vehicles assembly line (vibrating unit) workers and 69 axle assembly line (non-vibrating unit) workers. The study was conducted by questionnaire, physical examination, exposure evaluation, medical inspection, interviews and job observation.

Keywords— Vehicle assembly line, axle assembly line, CTS, hand-arm vibration, tendinitis, vibration

INTRODUCTION

CARPAL TUNNEL SYNDROME (CTS)

CTS is a condition in which tendons or ligaments in the wrist become enlarged. The main (median) nerve of the hand and its branches enter the hand through a narrow Passageway (Carpal tunnel) formed by wrist bones (Carpal bones) and the tough membrane that holds the bones together (transverse carpal ligament). The median nerve supplies sensation to the thumb, index finger, middle finger and in most people to part of the ring finger. Because this passageway is rigid, inflammation, swelling, or increase fluid retention may compress the nerve (Nerve entrapment), causing pain and numbness in the fingers (particularly the index, middle, and thumb) and eventually serious hand weakness.

SYMPTOMS OF CTS

The typical symptoms of CTS are tingling of the thumb and of the index, middle and ring fingers and night pain. The pain awakens the patient, but is often relieved by shaking, hanging, or massaging the hand. Pain may involve not only in the hand, but also the arm and the shoulder. Numbness and loss of manual dexterity occur in more advanced cases. Weakness of the hand also occurs, causing difficulty with pinch and grasp. The victim may drop objects or be unable to use keys or count change with the affected hand. The skin may dry because of reduced sweating.

Some of the main important of symptoms are as follows:

- Wrist pain
- Hand pain
- Weakness
- Grasping
- Tingling
- Numbness

VEHICLE ASSEMBLY LINE

In Automobile manufacturing industry job are done through multiple manual and semi-automatic operations. It is found to have a considerable difference in the way of doing the job at several work stations. The various components used in a four wheeler vehicle assembly line are follows:

i. **Sub- assembly suspension front and rear**: In this operation, the suspension is assembled with front and rear axles. It is made up of four huge and five-axis machining that are made from 7075 forgings specific alloy having weight around 313 kg. The operation is performed on a conveyor line in the company. Repetitive use of both hands is involved in the process. The operators engaged in this operation are eight.

ii. **Attach hoses flexible to rear axle brake pipe**: In this process, the hoses flexible are attached in to rear axle brake pipe. The brake hose is an integral part of the braking system and used to transmit brake fluid under hydraulic pressure from the brake pipe to the calipers. They are manufactured from reinforced rubber. It is performed on a moving conveyor, while assembly is done by air nut runner. Both hands are involved in the operation. The operators engaged in this operation are six.

iii. **Attach ALSV, DDU and tight sensing valve**: In this operation, ALSV, DDU are attached with sensing valve. Automatic load sensing valve (ALSV) is developed which can be used in air brake system in commercial vehicles. The dry distributing unit (DDU) dries moist compressed air through a desiccant bed. It maintains system pressure within a required range. The DDU is used in the circuit of an air brake system of an automobile. Repetitive use of right hand is involved in process. Operators engaged in this operation are five.

iv. **Attach stay Intercooler**: In this operation attach stay intercooler, the intercooler are fitted on the stay intercooler. It is made up of mild steel. The operation is performed on a moving conveyor vehicle assembly line. This operation involves lifting and holding the profile with finger extremities/hands. The operators engaged in this operation are eight.

v. **Attach 3 way joint hydraulic brake and brake pipe**: In this operation 3 way joint hydraulic brakes and brakes pipe is attached. 3 ways joint are manufactured from copper and copper-nickel. The brake pipe is a rigid pipe usually made of steel, and carries pressurized brake fluid from the master cylinder to the brake hoses. Steel or copper brake pipes from the main network of pipes supplying brake fluid to all the brake components. Repetitive use of both hands is involved in process. The operators engaged in this operation are five.

AXLE ASSEMBLY LINE

An axle is a central shaft for a rotating wheel or gear. On wheeled vehicles, the axle may be fixed to the wheels, rotating with them, or fixed to the vehicle, with the wheels rotating around the axle. Axles are integral component of most practical wheeled vehicles. In a live-axle suspension system, the axles serve to transmit driving torque to the wheel, as well as to maintain the position of the wheels relative to each other and to the vehicle body. For the analysis potential CTS symptoms amongst worker, worker engaged in axle manufacturing unit operation of XYZ manufacturing industry were involved in the study. The various components of the axle manufacturing and their function are as follows:

i. **Fitting of retainer**: In this operation, retainer is fitted in the axle shaft. It is a made up of steel, zinc plate. Retainer plates are a critical part in the retainment of any bolt in axle. The operation is performed on a work station. Repetitive use of right hand is involved in process. The numbers of operators engaged in this operation are six.
ii. **Fitting of oil seal**: In this operation, oil seal fitted is pushed with the help of a riveting machine. It is made up of rubber, Nitrile Buna-N 70, Silicone, fluoride rubber. Median nerve related muscles are fatigued in this operation involving thumb, index and middle finger extremities.
iii. **Fitting of gasket**: This operation function is very similar to oil seal but it is performed on a similar kind of special purpose machine, so that enforcement of oil seal joint to ensuring the leakage of hydraulic oil and air in the chamber. Both hands are involved in the operation. Operators engaged in this operation are nine.
iv. **Fitting of ball bearing**: In this operation, ball bearing is fitted in the axle shaft. A bearing in which the parts are separated by a ring of small freely rotating metal balls which reduce friction. It is the made up of steel or stainless steel. This operation involves lifting and holding the profile with finger extremities/hands. Operators engaged in this operation are eleven.
v. **Fitting of circlip**: In this process, Circlips are a type of retaining ring. They are typically made from carbon steel, stainless steel or beryllium copper. Median nerve related muscles are fatigued in this operation involving thumb, index and middle finger extremities.

EXPERIMENTATION

FISHER'S EXACT TEST

It is used to check statistical significance by 2 × 2 contingency tables. In present study Fisher's exact test has been done to check significance for all the symptoms obtained in collected data for vehicle assembly line and axle assembly line workers for their comparison. Notations a, b, c and d are assigned to cells for Fisher's exact test and the grand total is assigned the notation 'n' and are presented below in Table 1.

Table 1.: A 2 × 2 contingency table set-up used for Fisher's exact test

Description	Vehicle Assembly Line	Axle Assembly line	Total
Symptom present (test positive)	a	b	a+b
Symptom present (test positive)	c	d	c+d
Total	a + c	b + d	a+b+c+d = n

The test is done on categorical data that result from classifying situation in two different ways. The probability value from the test is computed by the hyper geometric distribution as following (Montgomery, 2005)

$$P = \frac{\binom{a+b}{a}\binom{c+d}{c}}{\binom{n}{a+c}} = \frac{(a+b)!(c+d)!(a+c)!(b+d)!}{a!b!c!d!n!}$$

Where, the number of observations obtained for analysis is small (sample size ≤ 30).

ANALYSIS USING FISHER'S EXACT TEST

Hand arm vibration (HAV) exposed workers often experience tingling and numbness in their fingers. These symptoms can be intermittent or have a short duration if caused by the vibrations per sec. Patients can easily interpret symptoms differently or may have another definition for the symptom, which may confuse the picture of how common the HAVS is (Edlund, 2014). Symptoms related to CTS are numbness, tingling, difficulty in grasping, weakness, hand pain, wrist pain, positive Tinel's and Phalen's sign. These symptoms amongst vibrating and non-vibrating unit workers with their percentage of occurrence are obtained from the collected data and significance are checked for the symptoms as shown in Tables 2, 3, 4, 5, 6, 7, 8, 9, 10.

Table 2.: Survey based CTS symptoms data for Numbness

Symptoms	Vehicle Assembly Line	Axle Assembly line	Total
Numbness	21	9	30
No Numbness	48	60	108
Total	69	69	138

Table 3.: Survey based CTS symptoms data for Tingling

Symptoms	Vehicle Assembly Line	Axle Assembly line	Total
Tingling	26	11	37
No Tingling	43	58	101
Total	69	69	138

Table 4.: Survey based CTS symptoms in Difficulty data for Grasping

Symptoms	Vehicle Assembly Line	Axle Assembly line	Total
Grasping	22	10	32
No Grasping	47	59	106
Total	69	69	138

Table 5.: Survey based CTS symptoms data for weakness

Symptoms	Vehicle Assembly Line	Axle Assembly line	Total
weakness	24	19	43
No weakness	45	50	95
Total	69	69	138

Table 6.: Survey based CTS symptoms data for hand pain

Symptoms	Vehicle Assembly Line	Axle Assembly line	Total
Hand pain	28	16	44
No Hand pain	41	53	94
Total	69	69	138

Table 7.: Survey based CTS symptoms data for wrist pain

Symptoms	Vehicle Assembly Line	Axle Assembly line	Total
Wrist pain	20	09	29
No Wrist pain	49	60	109
Total	69	69	138

Table 8.: Survey based CTS symptoms data for Phalen's Test

Symptoms	Vehicle Assembly Line	Axle Assembly line	Total
Phalen's sign	27	14	41
No phalen's sign	42	55	97

Total	69	69	138

Table 9.: Survey based CTS symptoms data for Tinel's Test

Symptoms	Vehicle Assembly Line	Axle Assembly line	Total
Tinel's sign	31	18	49
No Tinel's sign	38	51	89
Total	69	69	138

Table 10.: Comparing of CTS symptoms Vehicle assembly line and Axle Assembly line

Symptoms	% of CTS symptoms in Vehicle Assembly Line	% of CTS symptoms in Axle Assembly line	p-value	Significance
Numbness	30.43	13.04	0.0222	($p<0.05$)
Tingling	37.68	15.94	0.0067	($p<0.05$)
Difficulty in grasping	31.88	14.49	0.0256	($p<0.05$)
Weakness	34.78	27.53	0.4625	Not significant
Hand pain	40.57	23.18	0.0439	($p<0.05$)
Wrist pain	28.98	13.04	0.0355	($p<0.05$)
Phalen's Sign	39.13	20.28	0.0248	($p<0.05$)
Tinel's sign	44.92	26.08	0.0323	($p<0.05$)

P-values are calculated through Fisher's exact test to find out the significant values of potential CTS sufferers. A parameter is significant if $0.01 < p < 0.05$, highly significant if $p < 0.01$ and not significant if $p \geq 0.05$.
From the above Table 10, it is observed that percentage of workers having all CTS symptoms i.e. numbness, tingling, difficulty in grasping, weakness, hand pain, wrist pain Phalen's sign and Tinel's sign is more in vibrating unit as compared to non-vibrating unit. Calculated p-value shows that there is a significant difference in the percentage of workers having symptoms except weakness (p-value = 0.4625). So weakness cannot be correlated to CTS in present study. As p-value is found to be minimum for tingling (p-value = 0.0067) it is the most significant CTS symptom related to CTS.

ANALYSIS USING CORRELATION

Data from health surveillance in vehicle assembly line and axle assembly line workers is classified according to potential CTS symptoms. To study the correlation between vehicle and axle assembly line for potential CTS symptoms, a hypothesis is assumed that the use of vibration tool does not affect potential CTS symptoms.

Table 11.: Vibrating and non-vibrating unit workers based potential symptom data for Correlation analysis

	Num-bness	**Tingling**	**Difficulty in grasping**	**Hand pain**	**Wrist pain**	**Phalen's Sign**	**Tinel's Sign**
No. of workers with symptom in Vehicle Assembly line (X)	21	26	22	20	20	27	31
No. of workers with symptom in Axle Assembly line (Y)	9	11	10	14	9	14	18

The values of ΣX^2, ΣY^2 and $\Sigma X.Y$ are calculated from survey based potential CTS symptoms data from the equation to get the correlation coefficient (r).

Table 12.: Calculated corresponding values of dependent and independent variables

X	Y	X^2	Y^2	X.Y
21	9	441	81	189
26	11	676	121	286
22	10	484	100	220
20	14	400	196	280
20	9	400	81	180
27	14	729	196	378
31	18	961	324	558
$\Sigma X=167$	$\Sigma Y=85$	$\Sigma X^2=4091$	$\Sigma Y^2=1099$	$\Sigma XY=2091$

$$r\ (\text{correlation coefficient}) = \frac{\sum x.y}{\sqrt{(\sum x^2.\sum y^2)}} = \frac{2091}{\sqrt{(4091x1099)}} = 0.986$$

Significance t-test value is obtained by putting correlation coefficient (r) in equation

$$t = r\sqrt{N-2}/\sqrt{1-r^2}$$

$$t = 0.986\sqrt{7-2}/\sqrt{1-(0.986)^2} = 13.222$$

Standard value of significance t-test for degree of freedom 5, at 5% level is equal to 2.015. Since calculated value of t-test (13.201) is more than standard value (2.015), so the alternative hypothesis is rejected. It concludes that CTS symptoms are affected by use of vibration tool.

RESULT AND CONCLUSION

From Fisher's exact test, it is observed that percentage of workers having all CTS symptoms i.e. numbness, tingling, difficulty in grasping, weakness, hand pain, wrist pain, Phalen's sign and Tinel's sign is more in vehicle assembly line as compared to axle assembly line.

Calculated p-value shows that there is a significant difference in the percentage of workers having symptoms except weakness. As p-value is found to be minimum for tingling, it is the most significant CTS symptom related to CTS.

By correlation, it is observed that standard value of significance t-test for degree of freedom 5, at 5% level is equal to 2.015. Since calculated value of t-test is more than standard value, so the alternative hypothesis is rejected. It concludes that CTS symptoms are affected by use of vibration tool.

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