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CARPALTUNNELSYNDROMESYMPTOMSANDASSOCIATEDRISKFACTORSFORASSEMBLYLINEWORKERSENGAGEDINSHOCKERMANUFACTURINGINDUSTRIESASTUDY

Carpal Tunnel Syndrome Symptoms and Associated Risk Factors for Assembly Line Workers Engaged in Shocker Manufacturing Industries: A Study

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Abstract- The Carpal Tunnel Syndrome (CTS) and associated risk factors for shocker manufacturing industries in Haryana were carried out. A comparison of CTS and other upper hand extremities amongst traditional and semi-ergonomic shocker manufacturing workers in actual industrial environment has been analysed through questionnaire and physical tests. Fisher's exact test and 't' test are used for statistical data analysis. From Fisher's exact test, it is observed that due to wrist/hand problems 80 % of traditional and 20 % of semi-ergonomic shocker manufacturing workers ($p < 0.05$), have been unable to perform the usual activities. The results reflect that the traditional shocker manufacturing workers are more CTS symptoms occurrence than the semi-ergonomic shocker manufacturing workers. From 't' test, it is found that there is significant difference in grip strength of dominant and non-dominant hand for high repetitive work as calculated t-ratio values 5.162 and 3.099 respectively are more than standard value 2.048.

Keywords: musculoskeletal disorders, carpal tunnel syndrome, tinel's sign, phalen's sign, fisher's exact test, 't' test.

I. Introduction

This paper presents analysis of Carpal Tunnel Syndrome (CTS) associated risk factors and exposure to repetition among assembly line workers engaged in traditional and semi-ergonomic shocker manufacturing industries in order to help reduce the work-related musculoskeletal disorders (WMSDs) in the upper-body extremities among assembly workers. An assembly line consists of a series of workstations, in which particular operations (set of assembly tasks) are executed repeatedly to increase line efficiency such as maximizing productivity (Carnahan et al., 2001, Xu et al., 2012). Musculoskeletal disorders (MSDs) refers to conditions where the workers have experienced discomfort in one or multiple body parts (neck, shoulder, back, elbow, hand, wrist, hip and knee), pain in the joints, tingling, and swelling. MSDs are common occupational diseases among assembly line workers due to repetitive motions or heavy workloads (Carayon et al., 1999). The assembly line workers of auto industry are one of several industries that have high incidence of MSDs (Ulin et al., 2004, Ferguson et al., 2011). One important risk factor might be the repetitive awkward posture of the worker relative to the work while trying to access different tasks in auto assembly line. Previous studies have shown that awkward postures increase the risk of MSDs [Silverstein et al., 1997, Punnet et al., 2004, Keyserling et al., 2005). Literature reviews of the evidence indicate that reducing workplace exposure to known risk factors including awkward posture results in reduced MSD risk [Bernard et al., 1997,Punnet et al., 2004).CTS is one of the type of MSDs brought on by over-worked, over-strained muscles of arms and hands, resulting in a loss of nerve conductivity and possibly leading to muscle strength problems (Jones et al., 2004). CTS results from the entrapment of the median nerve at the wrist. It is the most common entrapment syndrome causing frequent disability especially to working populations (Montgomery et al., 1995, Kostopoulos et al., 2004, Nordstrom et al., 1997, Nuckols et al., 2011). In the workplace, the risk of developing CTS is not confined to people in a single industry or job, but is especially common in those performing assembly line works such as manufacturing, sewing, finishing, cleaning, and packing etc. In fact, carpal tunnel syndrome is three times more common among assembly line workers than among data-entry personnel (U. S. Department of Health, 2012).

In the present study an attempt has been made to analyse CTS risk factors and symptoms in industrial activities of assembly profile section having manual operations such as case tube, cylinder and component cleaning, guide disk assembly, piston valve tightening, cylinder bottom pressing, piston rod circlipping, oil seal assembly etc. in two shocker manufacturing industries involving repetitiveness and over exertion. The Fisher's exact test and 't' test have been used for the analysis of

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CTS risk factors and symptoms. Geometric distribution is applied to get probability values in Fisher's exact test. For the selected physical profiles of the workers, the mean and standard deviation have been evaluated.

II. Materials and Methods

This work was carried out at two shocker industries in Haryana State, India. 140 workers of two shocker manufacturing industries, one is based on traditional and other on semi-ergonomic standards, were included in the study. There are 70 workforce in traditional, with a mean age of 39.29 ± 7.76 years, range 25-56, and 70 in semi-ergonomic, with a mean age of 29.23 ±3.54 years, range 23-40. The number of employees at the studied line was 91 in traditional and 85 in semi-ergonomic. In the present study we excluded those who did not work at the line, those who were off work due to sick-leave, pregnancy, education, chronic illness or due to other reasons. The study included those 140 that were present at their workstation on the day of examination of those specific workstations.

a) Shock Absorber Operations and Assembly Systems

The ergonomics study has been conducted on total 140 workers of two shocker manufacturing industries. One is based on traditional and other on semi-ergonomic standards having manual operations such as Case tube cleaning, Cylinder cleaning, Component cleaning, Guide disk assembly, Piston valve tightening/riveting, Cylinder bottom valve assembly/tightening, Oil filling in cylinder, Cylinder bottom pressing, Piston rod Circlipping, Oil seal assembly, Oil seal pressing and Beading and Sealing. Flow diagram of shock absorber assembly operations are shown in Figure 1. The photographs of shock absorbers are shown in Figure 2. Brief description of each operation is given below.

i. *Case tube cleaning*

In this operation the outer tube is cleaned extensively so that the shocker can work properly. It is made up of mild steel and having weighs around 2 kg. The operation is performed in a cleaning chamber with a suitable brush in both the industries.

ii. *Cylinder cleaning*

To remove foreign particles properly from outer surface of cylinder the phosphate solution is used. In semi-ergonomic industry both case tube cleaning and cylinder cleaning operations are performed at same work station.

iii. *Component cleaning*

Small components like bush, washer and oil seal are cleaned in a tray by the air pressure to wipe out the dust and foreign particles properly. The number of operators engaged in traditional shocker assembly unit are five whereas in semi-ergonomic industry are four. In both the industries the operation was performed in cleaning chamber.

iv. *Guide disk assembly*

In this operation guide disk is used for piston and main spring support. The assembly is done by spanner and air nut runner. The four numbers of operators are engaged in traditional and semi-ergonomic industries. In traditional manufacturing unit, the operation is performed by a conventional spanner at guide disk assembly station whereas in semi-ergonomic industry, it is performed on a moving conveyor by air nut runner.

v. *Piston valve tightening/riveting*

In both the industries, the operation is performed by a riveting press at piston valve tightening station. The operation is performed on moving conveyor and piston valve is tightened by riveting machine. The number of operators engaged is five in both the industries.

vi. *Cylinder bottom valve assembly/tightening*

In both the industries, the operation is performed at cylinder bottom valve assembly station and cylinder bottom valve is tightened by riveting press. The operation is performed on a moving conveyor and piston valve is tightened by air nut runner. The number of operators engaged in traditional and semi-ergonomic industries is four and five respectively.

vii. *Oil filling in cylinder*

For friction control the lubricant oil is poured manually in the cylinder in traditional manufacturing unit whereas in semi-ergonomic industry, it is done by oil filing machine. Number of operators engaged in traditional and semi-ergonomic industry is five and three respectively.

viii. *Cylinder bottom pressing*

In this operation, after tightening the cylinder bottom valve, cylinder bottom is pressed by five tonnage presses. In traditional industry four operators are engaged whereas in semi-ergonomic industry three operators are engaged.

ix. *Piston rod circlipping*

In traditional industry the operation is performed with the help of conventional spanner whereas in semi-ergonomic industry the operation is performed by air nut runner. The operator engaged in this operation is four in both the industries.

x. *Oil seal assembly*

Oil seal prevents the oil leakage from cylinder during movement of piston in cylinder. In this operation oil seal is assembled to the top of cylinder. It contains rubber seal, valve inlet and a nut which is assembled manually with the help of spanner in both industries. The operators engaged in this operation are five in both the industries.

xi. *Oil seal pressing*

In this operation, oil seal assembly is pushed with the help of a riveting machine in both the industries. The number of operators engaged in the operation is five in both the industries.

xii. *Beading and sealing*

In beading operation, the casing chamber of shocker is closed with special purpose machine called beading machine. In traditional manufacturing unit, five operators are engaged. The sealing operation is similar to beading operation but it is performed on a similar kind of special purpose machine, for the enforcement of beading joint to ensure the leakage of hydraulic oil and air in the casing tube chamber. In semi-ergonomic industry, the beading and sealing operation is performed on the same machine and total eleven operators are engaged in this combined task.

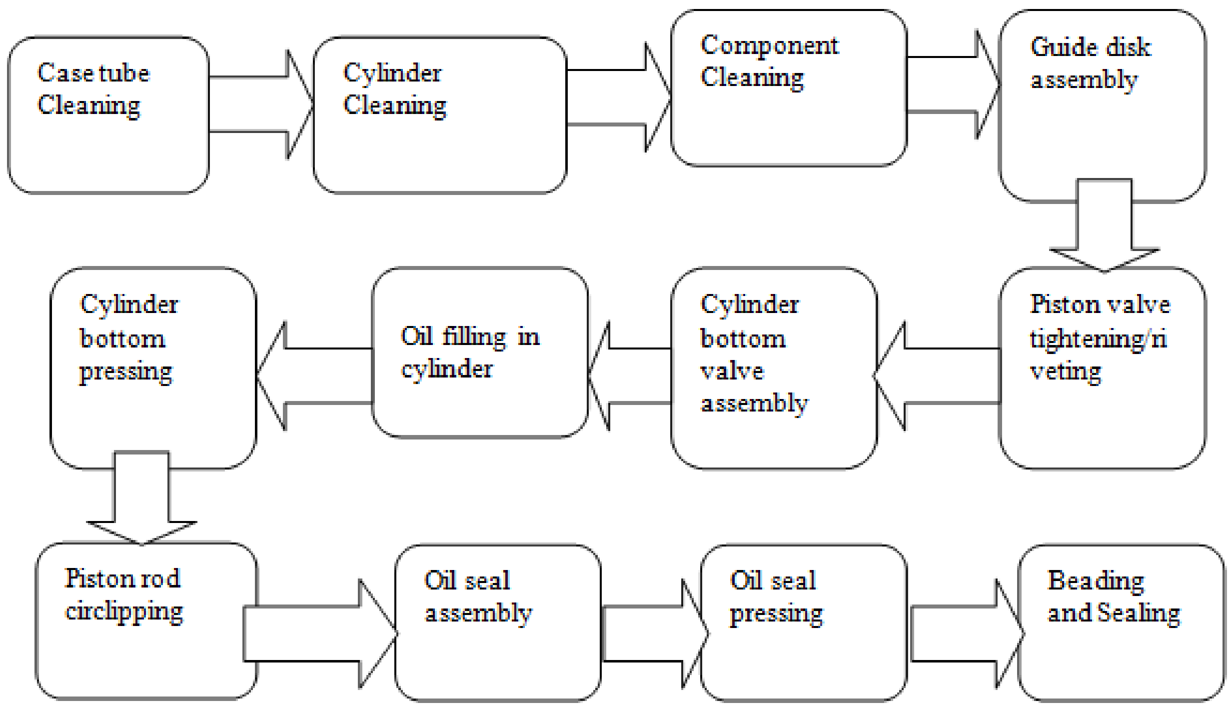

Figure 1 : Flow Diagram of Assembly Process of Shock Absorber

Figure 2 : Photographs of two and four wheeler shocker

b) Methods

The study was conducted at two shocker manufacturing plants. The companies provided a list of all jobs in the facility. The present study was conducted in traditional and semi- ergonomic assembly profile section. The workers were interviewed and examined at the work-site. The health questionnaire was designed andstatistical measurements were taken. Verbal consent of the workers was being taken and physical tests have been conducted. The health questionnaire included statistical description, investigation through physical examination, CTS symptom severity scale and on-job observation. Physical examination included height, weight, Body Mass Index (BMI), grip strength (dominant hand) and grip strength (non- dominant hand) measurement in assembly line as shown in Table 1. All physical examinations were being conducted through analog instruments. Readings were noted and tabulated. The descriptive statistics of the parameters with mean and standard deviation were computed and shown in the Table 1.

Hand grip strengths of dominant and non-dominant hands were taken so as to find out there relationships with potential CTS symptoms. CTS symptom severity scale is divided into four levels, namely 0, 1, 2 and 3. The level 0 for no, 1 for mild, 2 for moderate, and 3 is for severe CTS symptoms condition. No means zero pain, one means pain in APB muscle. Mild means pain in APB and FPB muscle, moderate means pain in fingers, thenar muscles and hands occasionally, severe means intolerable pain in fingers, thenar muscles, hands, elbow up to shoulder. CTS symptom severity scale has been applied upon potential CTS symptoms namely wrist pain, hand pain, numbness, tingling, difficulty in grasping and weakness to investigate the impact of CTS symptoms. Repetitiveness in the job has been categorized into two levels namely high and low based on cycle time. A ''high repetition'' job task was defined as one with a cycle time $\leq$15s and the job task classified as ''low repetition'' with a cycle time $\geq$15s and $\leq$3 0s. The physical examination included 4 items namely shoulders, hands, wrist and fingers. The work exposure evaluation was done in two ways; the workers own opinion in the questionnaire and an evaluation by the investigators including an ergonomic study. The whole examination took place in the supervisor's office, nearby the actual workstation. The results from these three sources were compared for each of the operations investigated. Workers at the same workstation did the same job, and there was job rotation every two hours. The standard values of weight of the job and magnitude of the force applied during operations by the workers was provided by the company.

Table 1 : Statistical ergonomic data of two shocker manufacturing assembly line workers

Factor of concern	Traditional Shocker Manufacturing workers (Mean ± S.D.)	Semi-ergonomic Shocker Manufacturing workers (Mean ± S.D.)
Number	70	70
Age (years)	39.29 ± 7.76	29.23 ±3.54
Weight (kg)	67.54 ± 7.91	64.33 ± 5.60
Height (Meter)	1.667 ± 0.072	1.664 ± 0.067
BMI (kg/m^2)	23.29± 0.65	23.18 ± 0.59
Grip strength (Dominant hand) (kg)	42.06 ± 16.57	50.67 ± 18.83
Grip strength (Non-Dominant hand) (kg)	39.27 ± 14.72	47.07 ± 18.07
Employment time at present site (years)	12.57 ± 7.40	4.57 ± 3.08

c) Statistical tools for CTS analysis

Following statistical tools have been used for CTS analysis.

i. Fisher's Exact Test

Fisher's exact test is used to check statistical significance of 2×2 contingency Tables [18]. In present study Fisher's exact test has been used to check all the symptoms of CTS in collected data of traditional and semi-ergonomic industries workers for comparison on the basis of response of workers for all the symptoms in yes or no. 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 in Table 2.

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

Description	Traditional shocker manufacturing worker	Semi-ergonomic shocker manufacturing worker	Total
Symptom Present (Test positive)	a	b	a + b
Symptom not Present (Test negative)	c	d	c + d
Total	a + c	b + d	n

The probability value p is computed by the hyper geometric distribution and expressed as

$$p = \frac{\binom{a+b}{a}!\binom{c+d}{c}!}{\binom{n}{a+c}!} = \frac{(a+b)!(c+d)!(a+c)!(b+d)!}{a!b!c!d!n!} \quad (1)$$

where the number of observations obtained for analysis is small (sample size ≤ 30) (Montgomery, 2005).

ii. 't' test

The t' test is used to determine the statistical significance of the difference between the means of two samples belonging to low and high repetitive work.Two independent samples of size n1 and n2 with means $\overline{X_1}$ and $\overline{X_2}$ and standard deviations S1 and S2 can be compared by testing the hypothesis that the samples come from the same normal population. To carry out the test, the statistic 't' can be calculated as follows:

$$t = \frac{\overline{X_1} - \overline{X_2}}{S_p} \times \sqrt{\frac{n_1 n_2}{n_1 + n_2}} \quad (2)$$

where

$\overline{X_1}$ = mean of the first sample,

$\overline{X_2}$ = mean of the second sample,

n_1 = number of observations in the first sample,

n_2 = number of observations in the second sample,

S_p = pooled or combined standard deviation,

Standard deviation 'S' for each sample can be calculated as

$$S = \sqrt{\frac{\sum(X - \overline{X})^2}{n - 1}} \quad (3)$$

where n is number of observations in each sample

From the number of observations and standard deviation of the two samples, the pooled estimate of standard deviation (S_p) can be obtained as follows:

$$S_p = \sqrt{\frac{(n_1 - 1)S_1{}^2 + (n_2 - 1)S_2{}^2}{n_1 + n_2 - 2}} \quad (4)$$

If the calculated value of t be greater than t0.05, the difference between the sample means is said to be significant at 5% level of significance otherwise data is consistent with the hypothesis (Gupta, 2001).Repetitiveness in the job has been categorized into two levels namely high and low based on cycle time.

III. Results and Discussions

a) Potential CTS symptoms based analysis by Fisher's exact test

The potential CTS symptoms like hand pain, wrist pain, numbness, tingling, difficulty in grasping, weakness, Tinel's sign, and Phenal's sign in traditional and semi-ergonomic shocker manufacturing workers with their percentage of presence are computed from the collected data and Eq. 1. The p-value so obtained is used to check the significance of the symptoms as shown in Table 3.

Table 3 : Test of difference between traditional and semi-ergonomic shocker manufacturing workers considering CTS related symptoms, and by applying Fisher's Exact Test

Symptoms	Traditional shocker manufacturing worker			Semi-ergonomic shocker manufacturing worker			p–value	Significance
	No. of workers	CTS symptoms Sufferer	% Percentage	No. of workers	CTS symptoms Sufferer	% percentage		
Hand pain	10	2	20	5	1	20	0.4945	Not Significant
Wrist pain	12	1	8.33	3	1	33.33	0.3428	Not Significant
Numbness	5	4	80	12	2	16.66	0.0266	Significant ($P < 0.05$)
Tingling	10	5	50	12	1	8.33	0.0405	Significant ($P < 0.05$)
Difficulty in grasping	5	4	80	10	2	20	0.0449	Significant ($P < 0.05$)
Weakness	7	1	14.2 8	3	1	33.33	0.4660	Not Significant
Tinel's sign	12	8	66.67	11	2	18.18	0.0237	Significant ($P < 0.05$)
Phenal's sign	9	5	55.55	14	2	14.28	0.0467	Significant ($P < 0.05$)

From the above Table 4 it is observed that due to wrist/hand problems 80 % of traditional and 20 % of Semi-ergonomic shocker manufacturing workers ($p < 0.05$), have been unable to perform the usual activities. The data analyzed from questionnaire also show that traditional shocker manufacturing workers have more percentage of CTS symptoms like numbness, tingling, Tinel's and Phalen's sign. Tinel's sign occurred in 66.67 % of the traditional and 18.18 % of the Semi-ergonomic shocker manufacturing workers ($p < 0.05$). Phalen's sign also show almost similar trend. Hand pain, wrist pain and feeling of weakness cannot correlate to CTS in the present study, as these are recognized as insignificant by Fisher's exact test. The results reflect that the traditional shocker manufacturing workers had more CTS symptoms occurrence than the Semi-ergonomic shocker manufacturing workers.

b) Physical profiles based comparison using 't' test

The collected data from questionnaire and physical tests is summarized based on age, height, weight, BMI, grip strength (dominant and non-dominant) in high and low repetitiveness work of traditional and Semi-ergonomic shocker manufacturing units as shown in Table 4 and Table 5 respectively. The descriptive statistics of the parameters with mean, standard deviation and range have also been mentioned in these Tables.

Table 4 : Ergonomic Statistical Analysis for High Repetitive Work

	Variable	Unit	Mean	Standard Deviation	Range
1.	Age	Years	44.87	7.22	56-34
2.	Height	Meter	1.646	0.073	1.78-1.6
3.	Weight	Kg	63.06	6.34	73-50
4.	BMI	kg/m2	23.21	0.77	21.40-24.10
5.	Grip strength (Dominant hand)	Kg	34.81	2.40	39-30
6.	Grip strength (Non-Dominant hand)	Kg	35.25	2.97	40-30
7.	Employment time at present site	Years	17.43	7.20	28-7

Table 5 : Ergonomic Statistical Analysis for Low Repetitive Work

	Variable	Unit	Mean	Standard Deviation	Range
1.	Age	Years	41.08	5.09	52-32
2.	Height	Meter	1.672	0.007	1.78-1.53
3.	Weight	Kg	65.14	8.02	75-50
4.	BMI	Kg/m^2	23.17	0.90	24-21.5
5.	Grip strength (Dominant hand)	Kg	38.85	1.79	41-35
6.	Grip strength (Non-Dominant hand)	Kg	38.07	1.77	41-36
7.	Employment time at present site	Years	15.35	6.47	29-3

In order to analyse the two sets (i.e. for high and low repetitive work) of data of physical profile given in Table 4 and Table 5, difference between means of each variable and corresponding 't' values are calculated and tabulated in Table 6.

Table 6 : Comparison between High and Low Repetitiveness Workers on Physical Variables

S. No.	Variable	Mean		Diff. Between means	't' ratio
		High Repetitive	Low Repetitive		
1.	Age	44.87	41.08	3.79	1.638
2.	Height	1.646	1.672	0.026	1.324
3.	Weight	63.06	65.14	2.08	0.792
4.	BMI	23.21	23.17	0.04	0.131
5.	Grip strength (Dominant hand)	34.81	38.85	4.04	5.162
6.	Grip strength (Non-Dominant hand)	35.25	38.07	2.82	3.099
7.	Employment time at present site	17.43	15.35	2.08	0.827

The Table 6 revealed that there were no significant differences in age, height, weight, BMI and employment time at present site of high and low repetitive work, as the obtained t-ratio values are 1.638, 1.324, 0.792, 0.131 and 0.827 respectively which are less than standard value 2.048 But there was significant difference in Grip strength (Dominant and non-dominant hand) of high repetitive work at the obtained t-ratio values are 5.162 and 3.099 respectively which are above the standard value 2.048 required for the t-ratio to be significant at 0.05 level of significance with 28 degree of freedom.

IV. Conclusion

From Fisher's exact test, it is observed that the traditional shocker manufacturing workers had more CTS symptoms occurrence than the Semi-ergonomic shocker manufacturing workers. The results elicit that due to wrist/hand problems 80 % of traditional and 20 % of Semi-ergonomic shocker manufacturing workers ($p < 0.05$), have been unable to perform the usual activities. Tinel's sign occurred in 66.67 % of the traditional and 18.18 % of the Semi-ergonomic shocker manufacturing workers ($p < 0.05$). Phalen's sign also show almost similar trend. Hand pain, wrist pain and feeling of weakness cannot correlate to CTS in the present study, as these are recognized as insignificant by Fisher's exact test. The 't' test result revealed that there were no significant differences in age, height, weight, BMI and employment time at present site of high and low repetitive work, as the obtained 't' ratio values are 1.638, 1.324, 0.792, 0.131 and 0.827 respectively which were less than standard value 2.048. But there was significant difference in grip strength (dominant and non-dominant hand) of high repetitive work at the computed 't' ratio values were 5.162 and 3.099 respectively which are above the standard value 2.048 required for the 't'-ratio to be significant at 0.05 level of significance with 28 degree of freedom. The study has good prospect in reducing the health hazards of CTS by keeping a continuous check on critical limits of risk factors. As a preventive measure for CTS well sound job rotation policy can be adopted and an employee wellness program can be implemented that include hand/wrist simple stretching exercises to be performed before the shift begins and/or during the first 5-20 minutes of each shift. However, research has not conclusively shown that these workplace changes prevent the occurrence of carpal tunnel syndrome.

V. Acknowledgment

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References Références Referencias

1. Bernard, B. (1997). Musculoskeletal Disorders and Workplace Factors. A Critical Review of Epidemiologic Evidence for Work-related Musculoskeletal Disorder of the Neck, Upper Extremity, and Low Back, DHHS (NIOSH) Publication, 97-141.
2. Carayon, P., Smith, M. J., and Haims, M. C. (1999). Work organization, job stress, and work-related musculoskeletal disorders. Human Factors, 41(4): 644-651.
3. Carnahan, B. J., Norman,B. A., and Redfern, M. S. (2001). Incorporating physical demand criteria into assembly line balancing. IIE Transactions, 33(10): 875–887.
4. Ferguson, S. A., Marras, W. S., Allread, W. G., Knapik, G. G., Vandlen, K. A., Splittstoesser, R. E., and Yang, G. (2011). Musculoskeletal disorder risk as a function of vehicle rotation angle during assembly tasks. Applied Ergonomics, 42: 699- 709.
5. Gupta, S. P. (2001). Statistical methods, Sultan chand and sons,911-916.
6. Jones, T., and Kumar, S. (2004). Occupational injuries and illnesses in the sawmill industry of Alberta, International Journal of Industrial Ergonomics, 33: 415–427.
7. Keyserling, W. M., Sudarsan, S. P., Martin, B. J., Haig, A. J., Armstrong, T. J. (2005). Effects of low back disability status on lower back discomfort during sustained and cyclical trunk flexion, Ergonomics, 48: 219-233.
8. Kostopoulos, D. (2004). Treatment of carpal tunnel syndrome: a review of the non- surgical approaches with emphasis in neural mobilization, Journal of Bodywork and Movement Therapies, 8(1): 2-8.
9. Montgomery, D. C. (2005). Design and Analysis of Experiments, Wiley Higher Education.
10. Montgomery, K. (1995), A nonsurgical approach to Carpal Tunnel Syndrome, Proceedings of the International Forum on New Science, Fort Collins, Colorado USA, 13-17.
11. Nordstrom, D. L., Vierkant, R. A., Destefano, F., and Layde, P. M. (1997). Risk factors for carpal tunnel syndrome in a general population,Occup Environ Med, 54 (10) :734-740.
12. Nuckols, T., Harber, P., Sandin, K., Benner, D., Weng, H., Shaw, R., Griffin, A., and Asch, S. (2011). Quality Measures for the Diagnosis and Non-Operative Management of Carpal Tunnel Syndrome in Occupational Settings, J Occup Rehabil, 21:100–119.
13. Punnet, L., and Wegman, D. H. (2004). Work-related musculoskeletal disorders: the epidemiologic evidence and the debate, J. Electromyogr. Kinesiol, 14: 13-23.
14. Punnet, L., Gold, J., J. Katz, N., Gore, R., D. and Wegman, H. (2004). Ergonomic stressors and upper extremity musculoskeletal disorders in automobile manufacturing: a one year follow up study, Occup. Environ. Med, 61: 668-674.
15. Silverstein, B. A., Stetson, D. S., Keyserling, W. M., and Fine, L. F. (1997). Work-related musculoskeletal disorders: comparison of data sources for surveillance,Am. J. Ind. Med, 31: 600-608.
16. U. S. Department of Health, (2012). Carpal Tunnel Syndrome, National Institutes of Health, Bethesda, MD.
17. Ulin, S. S., and Keyserling, W. M. (2004). Case studies of ergonomic interventions in automobile parts distribution operations. J. Occup. Rehabil, 14: 307-326.
18. Xu, Z., Ko, J., Cochran, D. J., and Jung, M.C. (2012). Design of assembly lines with the concurrent consideration of productivity and upper extremity musculoskeletal disorders using linear models. Computers & Industrial Engineering, 62: 431–441.