Impact of Cycle Time on Potential CTS

Md. Sarfaraz Alam[1], Dr. Urmi Ravindra Salve[2], Naresh Kumar[3], Dr. Manoj Kumar[4], Dr. Zulquernain Mallick[5]

[1, 2]Department of Design, Indian Institute of Technology Guwahati, ASSAM
[3, 4]Department of ME, Sant Longowal Institute of Engineering & Technology, PUNJAB
[5]Department of ME, Faculty of Engineering & Technology, Jamia Millia Islamia, NEW-DELHI

***Abstract*— *Upper limb musculoskeletal symptoms and upper-limb musculoskeletal disorders (MSDs) have been found to be common in the working population. Carpal tunnel syndrome (CTS) is the most commonly studied entrapment neuropathy caused by compression of the median nerve as it passes through the carpal tunnel beneath the flexor retinaculum. The present study is conducted among person engaged in connecting rod manufacturing industry to check effect of cycle time of operation on potential CTS symptoms. The study sample consists of 103 workers for data collection. The study was conducted by questionnaire, physical examination, wrist angle evaluation and on job observation. Correlation analysis and Correlation analysis using IBM SPSS 20, it is revealed that Value of Pearson correlation coefficient is found to be -0.930 which is same as the value calculated manually. So analysis by SPSS 20 also confirms that there is very high negative correlation between cycle time and percentage of CTS sufferers.*

Keywords*— *Carpal Tunnel Syndrome, Cycle time, Repetitive Strain Injury.

I. INTRODUCTION

Repetitive Strain Injuries (RSIs) are injuries of the musculoskeletal and nervous systems that may be caused by repetitive tasks, forceful exertions, vibrations, mechanical compression (pressing against hard surfaces), or sustained or awkward positions. Repetitive Strain Injury is also called regional musculoskeletal disorder (MSD), repetitive motion disorder (RMD),Occupational Overuse Syndrome (OOS),Repetitive Motion Syndrome (RMS), Repetitive Motion Injuries (PEOSH**,** 2003).

Upper limb musculoskeletal symptoms and upper-limb musculoskeletal disorders (MSDs) have been found to be common in the working population (Roquelaure et al., 2006). Twenty-eight percent of all workplace injuries requiring time away from work that were reported to the Bureau of Labor Statistics were MSDs (BLS, 2010). Also, a high incidence rate of 31.2 cases per 10,000 full-time equivalent workers was found for work-related MSDs in the agriculture industry (BLS, 2009). Previous analyses of workers' compensation data from large herd milking operations in Colorado indicated that nearly 50% of livestock-handling injury claims involved workers performing work tasks in the milking parlor. Nearly 27% of the injuries were to the wrist, hand, and fingers (Douphrate et al., 2009). Previous studies by the National Research Council have suggested that up to 95% of upper-extremity injuries may be attributable to workplace factors (N.R.C. 2001). Because RSI conditions are invisible, the general public tends to be unaware of the pain and distress suffered by those affected. Due to a lack of relevant research and information, many people are unclear as to the origin and treatment of these conditions.

1.1 Carpal Tunnel Syndrome

Carpal tunnel is a closed space between the fibrous band which functions as support for the wrist joint and the wrist bone. Median nerve providing sensations to thumb, index, middle and radial half of ring fingers passes through this tunnel. Carpal tunnel syndrome (CTS) is the most commonly studied entrapment neuropathy caused by compression of the median nerve as it passes through the carpal tunnel beneath the flexor retinaculum. It is a classic example of chronic compression neuropathy of the median nerve within the carpal tunnel at the wrist and a frequently encountered cause of pain, numbness and tingling in the upper extremities (Atroshi et al., 1999). The impairment of the median nerve within the carpal canal is secondary to compression of the median nerve within the carpal tunnel resulting in mechanical compression and local ischemia. CTS is considered as a clinical entity and diagnosis is still based upon symptoms of numbness, tingling and/or burning in the distribution of the median nerve in the hand. Repetitive hand activity may cause thickening of the synovial lining of the tendons that share the carpal tunnel with the median nerve. Usual symptoms include numbness, tingling and pain predominantly in the median nerve distribution of the hand; however, the symptoms can frequently be present in all fingers of the hand or proximally in the forearm. The symptoms may or may not be accompanied by objective changes in sensation and strength of median-innervated structures in the hand (Werner and Andary, 2002).

https://dx.doi.org/10.22161/ijaers.4.1.7 ISSN: 2349-6495(P) | 2456-1908(O)

The carpal tunnel condition becomes so severe that it cannot let the proper function due to pressure on the median nerve where it passes into the hand via a gap (carpal tunnel) under a ligament at the front of the wrist (Okada et al., 2000). People with CTS experience difficulty in performing tasks such as unscrewing bottle tops, fastening buttons, or turning keys. CTS occur most commonly among age group above 30 (Kumar, 2010).

1.2 Symptoms of CTS

Primary symptoms include numbness and tingling. Secondary symptoms include pain, weakness and difficulty in grasping, all usually in the area of median nerve distribution. Symptoms gradually progress over weeks and months and in some cases over years. Though bilateral CTS is common, dominant hand is affected first and more severely than the other hand (Ashworth, 2005).

1.2.1 Numbness and Tingling

Patients may have numbness and tingling in the thumb, index, middle and radial half of ring fingers. Patients complain that there is dropping of things or things slip from their fingers without notice. Symptoms are intermittent and associated with driving, painting, newspaper reading, etc. Some report parenthesis in the whole hand which can be explained by autonomic fiber involvement (Ashworth, 2005).

1.2.2 Pain

It can be in the form of aching sensation over the anterior aspect of the wrist along with numbness and tingling. Pain or paresthesias can radiate either proximally to the forearm, elbow, and shoulder or distally to the palm or fingers. Proximal radiation can be due to other musculoskeletal disorders with which CTS is commonly associated. In CTS, pain starts at wrist and radiates proximally or wrist flexion exacerbates both proximal and distal radiation and also pain is relieved by rubbing or shaking the hand (Ashworth, 2005).

1.2.3 Weakness and Difficulty in Grasping

It is in the form of loss of power in the hand, particularly for precision grips involving thumb.

II. EXPERIMENTATION

The Present study focuses the identification of risk factors such as cycle time, on potential CTS symptoms such as hand pain, wrist pain, numbness, tingling, weakness and difficulty in grasping. The study sample consists of 103 connecting rod manufacturing workers for data collection. The study was conducted by questionnaire, physical examination, wrist angle evaluation and on job observation. A researcher administered questionnaire was used to obtain information on presenting signs and symptoms and possible risk factors for carpal tunnel syndrome. Health questionnaire form was designed according to the information required like age, height, weight, job experience, potential symptoms severity. Job categorization is then done according to level of repetition, force involved, consulting the concerned industrial experts and also by interviewing the workers. The participant ranges in age from 24 to 60 years with a mean of 42.85 (standard deviation (SD) = 8.72) years. The workers had been performing work for a mean of 14.69 years (SD 7.37). All the values of mean and standard deviation have been calculated by IBM SPSS version 20.

2.1 Correlation analysis

Correlation is often used as descriptive tool in non-experimental research. Two measures are correlated if they have something in common. The intensity of the correlation is expressed by a number called the coefficient of correlation, which is usually denoted by the letter (r)Although usually called the Pearson Coefficient of correlation, it was first introduced by Galton (1886) and later formalized by Karl Pearson (1896) and then by Fisher (1935). The coefficient of correlation is a tool used to evaluate the similarity of two sets of measurements (i.e. two dependent variables) obtained on the same observations. The coefficient of correlation indicates how much information is shared by two variables, or in other words, how much these two variables (x and y) have in common. The value of r (correlation coefficient) is given by

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

The following general rules are used in intercepting the value of r (correlation coefficient).

- When r = +1, it means there is perfect positive relationship between the variables.
- When r = -1, it means there is perfect negative relationship between the variables.

When r = 0, it means there is no relationship between the variables i.e. the variables are uncorrelated

The probable error of the coefficient of correlation helps in intercepting its value. With the help of probable error it is possible to determine the reliability of the value of coefficient of correlation. The probable error of the coefficient of correlation is obtained as follows:

$$\text{P.E.} = 0.6745\ \frac{(1 - r^2)}{\sqrt{N}}$$

Where r is the coefficient of correlation and N is the no. of pairs of observations.

- If the value of r is less than the probable error, there is no evidence of correlation, i.e. the value of r is not at all significant.

https://dx.doi.org/10.22161/ijaers.4.1.7 ISSN: 2349-6495(P) | 2456-1908(O)

- If the value of r is more than six times the probable error, the coefficient of correlation is practically certain i.e. the value of r is significant.

2.2 Analysis of cycle time and potential CTS symptoms by correlation analysis

Exposure to repetition alone has been found to increase the risk of CTS (Chiang et al., 1990; Silverstein et al., 1987). Repetition contributes to the development of CTS by affecting the soft structures of the wrist, resulting in the production of excess synovial fluid from the tendon sheaths located in the wrist, which in turn increases pressure on the median nerve (Colombini1998; Silverstein, 1985). Both passive hand and wrist movements as well as hand and wrist movements requiring the use of grips force, or deviated postures can increase the risk of CTS development (Drury, 1987). In this study, an attempt is made to study the effect of cycle time of operation on potential CTS symptoms by use of correlation analysis.

Data collected by health surveillance questionnaire is categorized into five groups on the basis of cycle time and percentage of CTS sufferers in all the cases as shown in the Table 1.

Table.1: Percentage of CTS sufferers for different groups of cycle time

Cycle time (second)	CTS sufferers	Non-CTS sufferers	Total no. of workers	% of CTS sufferers
0-10 sec	4	3	7	57.14
11-20 sec	14	22	36	38.88
21-30 sec	13	25	38	34.21
31-40 sec	5	11	16	31.25
41-50 sec	1	5	6	16.66

It is observed that as the cycle time increases, the percentage of workers suffering from CTS decreases.

To study the correlation between average cycle time and no. of CTS sufferers, a hypothesis is assumed that the cycle time affects the percentage of CTS sufferers. Here average cycle time is the independent variable (X) and percentage of CTS sufferers is the dependent variable (Y) as shown in the Table 2.

Table2: Survey based data for average cycle time and percentage of CTS sufferers

Cycle time (sec.)	<10	11-20	21-30	31-40	41-50
Average cycle time (sec.) (X)	7	13	25.25	35	43
% of CTS sufferers(Y)	57.1	38.8	34.2	31.2	16.6

The values of $\sum x^2$, $\sum y^2$ and $\sum x^2.y^2$ are calculated from survey based potential CTS symptoms data to get the correlation coefficient (r) as shown in the Table 3.

Table.3: Calculated corresponding values of dependent and independent variables

X	$x = X-\bar{X}$	x^2	Y	$y = Y-\bar{Y}$	y^2	x.y
7	-17.65	311.52	57.1	21.52	463.11	-379.82
13	-11.65	135.72	38.8	3.22	10.36	-37.51
25.25	0.60	0.36	34.2	-1.38	1.90	-0.82
35	10.35	107.12	31.2	-4.38	19.18	-45.33
43	18.35	336.72	16.6	-18.98	360.24	-348.28
$\sum X$= 123.25	$\sum x$= 0	$\sum x^2$= 891.44	$\sum Y$ = 177.9	$\sum y$ = 0	$\sum y^2$= 854.79	$\sum x.y$= -811.76

$$\text{where } \bar{X} = \sum X/N = 123.25/5 = 24.65$$

$$\text{and } \bar{Y} = \sum Y/N = 177.9/5 = 35.58$$

$$r \text{ (correlation coefficient)} = \frac{\sum x.y}{\sqrt{(\sum x^2.\sum y^2}} = \frac{\sum x.y}{\sqrt{(\sum x^2.\sum y^2}} = \frac{-811.76}{\sqrt{891.44x854.79}} = -0.930$$

Very high negative value of correlation coefficient indicates that there is strong negative correlation between average cycle time and percentage of CTS sufferers i.e. smaller the cycle time, more the chances of occurring CTS.

To check whether the value of r is significant or not, the probable error of the coefficient of correlation is obtained as

$$P.E. = 0.6745 \frac{(1-r^2)}{\sqrt{N}} = 0.6745 \frac{(1-(-0.930)^2)}{\sqrt{5}} = 0.0407$$

As the value of correlation coefficient is found to be more than six times the values of probable error, value of correlation coefficient is significant.

2.3 Impact of cycle time on CTS by correlation analysis using IBM SPSS20

SPSS stands for Statistical Package for the Social Sciences and is a comprehensive system for analyzing the data. This package of program is available for both personal and mainframe (or multi-user) computers. SPSS package consists of a set of software tools for data entry, data management, statistical analysis and presentation. SPSS integrates complex data and file management, statistical analysis and reporting function. SPSS can take data from almost any type of file and use them to generate tabulated reports charts and plots of distribution and trends, descriptive statistics and complex statistical analyses.

Features of SPSS:

(i). It is easy to learn and use.

(ii).It includes a full range of data management system and editing tools.

(iii). It provides in depth statistical capabilities.

(iv).It offers complete plotting, reporting and presentation features.

SPSS makes statistical analysis accessible for the casual user and convenient for the experienced user. The data editor offers a simple and efficient spreadsheet like facility for entering data and browsing the working data file. Result of the SPSS has been shown in Table 4.

Table.4: Correlation analysis output from SPSS 20

Correlations

		CT	CTS
CT**	Pearson Correlation	1	-.930*
	Sig. (2-tailed)		.022
	N	5	5
CTS**	Pearson Correlation	-.930*	1
	Sig. (2-tailed)	.022	
	N	5	5

*. Correlation is significant at the 0.05 level (2-tailed).

** CTS: Carpal Tunnel Syndrome

** CT: Cycle Time

Value of Pearson correlation coefficient is found to be -0.930 which is same as the value calculated manually. So analysis by SPSS 20 also confirms that there is very high negative correlation between cycle time and percentage of CTS sufferers.

III. CONCLUSION

In this present study, effect of forceful work, repetitive hand movements, Cycle time, awkward posture and several other risk factors has been studied on industrial workers in terms of potential CTS symptoms. Correlation analysis and IBM SPSS 20 were used to achieve the objectives. Correlation analysis was used to study the relation between cycle time and potential CTS symptoms. A very high negative value of correlation coefficient (r = -0.929) revealed that there is negative correlation between cycle time and potential CTS symptoms i.e. the percentage of CTS sufferers increases with decrease in cycle time. Result obtained by SPSS also confirms the negative correlation between cycle time and percentage of CTS sufferers.

The recommendations for preventing CTS symptoms occurrence among the workers engaged in manufacturing industry are:

- The risk factors analyzed in this study should be kept in mind for reducing the CTS occurrence.
- A preferential job allocation policy can be implemented such as more aged workers can be given less repetitive work and vice versa.
- Job rotation policy can be implemented to minimize the risk of CTS occurrence.

A study is required which can describe which factor is more or less dominating with respect to others factors. It is possible by use of advance statistical tools and statistical software.

ACKNOWLEDGEMENTS

We are highly obliged to the EMSON Tools Manufacturing Corp. Ltd. for conduct this study. We, the authors, thank Dr. M. K. Goyal from SLIET Longowal for the contribution to the first stage of his research and help in developing the questionnaire. We also thank to Prof. Dr. D. Chakrabarti, Dr. S. Pal, Dr. S. karmakar and members of Ergonomics Laboratory of Indian Institute of Technology for kind assistance at each step of this research.

REFERENCES

[1] Roquelaure, Y., Ha C., Leclerc, A., Touranchet, A., Sauteron, M., Melchior M, Imbernon, E., Goldberg M., "Epidemiologic surveillance of upper-extremity musculoskeletal disorders in the working population," Arthritis Care & Research, 2006, 55, 765-778.

[2] Douphrate, D.I., Rosecrance, J., Stallones, L., Reynolds, S.J., Gilkey DP., "Livestock-handling injuriesin agriculture: An analysis of Colorado workers' compensation data," American Journal of Industrial Medicine, 2009, 52, 391-407.

[3] Atroshi, I., Gummesson, C., Johnsson, R., Ornstein, E., Ranstam, J., Rosen, I., "Prevalence of carpal tunnel syndrome in a general population," JAMA, 1999, 281(2), 153-8.

[4] Werner, A., Robert, Andary, M., "Carpal tunnel syndrome: pathophysiology and clinical neurophysiology" Clinical Neurophysiology, 2002, 113, 1373–1381.
[5] Okada, M., Tsubata, O., Yasumato, S., Toda, N., and Matsumoto, T., "Clinical study of surgical treatment of carpal tunnel syndrome: Open versus endoscopic technique," Journal of orthopaedic surgery, 2000, 8, 19-25.
[6] Kumar M., Kumar M., Kumar S., Jindal O., Arora S. A. and Kumar R., "Analysis of APB Muscle by Surface Electromyography," International Journal of Engineering Studies, 2010, 305-312.
[7] Ashworth NL., "Clinical Evidence: Carpal tunnel syndrome," Issue 13, London, England; BMJ Publishing, 2005.
[8] Chiang H., Chen S., Yu K., Ko Y., "The occurrence of carpal tunnel syndrome in frozen food factory employees," 1990, Kao Hsiung Journal of Medicine and Science, 6: 73–80.
[9] Silverstein B., Fine L., Armstrong T., "Occupational factors and carpal tunnel syndrome," 1987, American Journal of Industrial Medicine 11, 343–358.
[10] Colombini D., "An observational method for classifying exposure to repetitive movements of the upper limbs," 1998, Ergonomics 41 (9) 1261–1289.
[11] Drury C., "A biomechanical evaluation of the repetitive motion injury potential of industrial jobs," 1987, Seminars in Occupational Medicine 2, 41–49.
[12] Daniella A. de O., Ana C. de C. Vieira, Marcelo M.V., "Pathophysiology and Prognostic Factors in Carpal Tunnel Syndrome after Median Nerve Decompression," Frontiers in Pathology and Genetics (FPG) Volume 1 Issue 3, December 2013.
[13] Yu Wenzhou, Yu T.S. Ignatius, Li Zhimin, Wang X., Sun Trevor, Lin Hui, Wan Sabrina ,Hong Qiu, Xie S., "Work-related injuries and musculoskeletal disorders among factory workers in a major city of China," Accident Analysis and Prevention 48, 2012; 457– 463.
[14] Widanarko B., Legg S., Stevenson M., Devereux J., Eng A., Mannetje A., Cheng Soo, Douwes J., Ellison-LoschmannLis, McLean D., Pearce N., "Prevalence of musculoskeletal symptoms in relation to gender, age, and occupational/industrial group," 201, International Journal of Industrial Ergonomics, 41: 561-572.
[15] Zetterberg C., Torsten O., "Carpal tunnel syndrome and other wrist hand symptoms and sign in male and female car assembly worker," 1999, International Journal of Ergonomics, 23 (2) 193-204.
[16] Ajimotokan H. A., "The effects of Coupling Repetitive Motion Tasks with a manually- stressed work environment," 2009, Researcher, 1, 37-40.
[17] Carlos H. Fernandes, Lia M. Meirelles, Jorge Raduan N., Luis R. Nakachima, João B. G. dos Santos, and Flavio F., "Carpal tunnel syndrome with thenar atrophy: evaluation of the pinch and grip strength in patients undergoing surgical treatment," 2013, American Association for Hand Surgery.
[18] Cartwright MS, Walker FO, Blocker JN, Schulz MR, Arcury TA, Gzywacz JR, Mora D, Chen H, Marín AJ, Quandt S.A., "The Prevalence of Carpal Tunnel Syndrome in Latino Poultry Processing Workers and Other Latino Manual Workers," J Occup Environ Med. 2012 February; 54(2): 198–201.
[19] Cartwright S. Michael, Walker O. Francis, Newman C. Jill, Schulz R. Mark, Arcury A. Thomas, Grzywacz G. Joseph, Mora C. Dana, Chen Haiying, Eaton Bethany, Quandt A. Sara, "One-Year Incidence of Carpal Tunnel Syndrome in Latino Poultry Processing Workers and Other Latino Manual Workers," 2014, American journal of industrial medicine, 57:362–369.