

Analysis of Ergonomic Methods used to Prevent Negative Effect in the Health of Workers in a Metallic Industry in Mexicali, Mexico

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ABSTRACT

An investigation of the negative effects in the health of workers of a metallic industry located in Mexicali city, was made, which they suffered daily, of discomfort in the head, neck, back and spine. This occurred when people of the manufacturing area of the industry that was evaluated developing operations that required great physical effort without adequate equipment and the industrial operations were repetitive. The manager and supervisors workers knew that this could happen, but they did not prepare to avoid that the people of the evaluated area did not present health symptoms regarding discomfort and pain of the health symptoms mentioned above. The analysis was made in 100 workers (30% women and 70% men), and were evaluated in the morning and evening shifts, which performed functions of lifting, loading and gluing pieces of window frames for homes made of aluminum material. The aluminum frames had a weight of 20 kilograms with repetitive operations of until 50 lift for each eight-hour shift, generating the discomfort and pain. The study was from 2017 to 2019, and more than 50% of the workers in the manufacturing areas, in the two shifts of the company, suffered from discomfort and pain in the mentioned body areas, which caused the concern of management and supervision personnel. The lack of an appropriate ergonomics or engineering support method was what caused this problematic situation. Based on the evaluation, the proposal of a system with exoskeleton to reinforce the operations of the industrial process presented.

Keywords: Occupational health, Occupational risk, Industry, Ergonomics.

1. Introduction

An evaluation was made, at the time it was detected a risk situation of workers which operated in the area of cut and gluing aluminum materials was made, which is used especially in houses of social interest in the Mexicali city, where are required thousands of frames to the construction activities (CEC, 2006). These industrial processes are high risk when they do not have the appropriate equipment and tools, with operations repetitively, and in addition to not elaborate these industrial activities. Other factor was the elaboration of the industrial processes without an ergonomic method and with inappropriate posture, which initiated a small nuisance in the aforementioned body areas previously (G. Wallace, 2011). Of the 100 workers evaluated, at least five of each turn of each day, and this is 45%, were missing from one to two days, due to inconvenience, which resulted in staff turnover of the same company or hiring of new workers (Houshang Alamdari, 2017; Robson LS et al, 2011). The management and supervisory personnel were concerned that this caused errors by new personnel in this area and those were not trained were susceptible to suffering from a health symptom mentioned above. This contributed to delays in the fabrication in any area of this industry and in to the customer, and the customer requesting financial compensation for the delay of the finished product.

Occupational health vs Industrial operations

Industrial operations of a manufacturing area were evaluated, with rigid activities and with a high risk to suffer discomfort and pain in dorsal parts mentioned above of the body of workers. When analyzing the lift, charge and

sustain metallic pieces used to fabricate the frames of windows, was observed that this industrial operation not was made with an ergonomic manner required, which generated that the employees suffered a negative effect on their health with discomfort and pain essentially head, neck, back and spine (Leticia Arenas-Ortiz et al, 2013). Even when the employees of the company were constantly trained, the lack of awareness of the personnel to elaborate the operations in an adequate way, caused that the workers continued to suffer from discomfort and pain in the mentioned areas of the body, and it was necessary generate the staff rotation continuously (Sierra OA et al, 2010). According to the General Mexican Health Institution, about 15,000 workers suffer from dorsal diseases a year (IMSS, 2018). The constant repetitiveness of movements of lift, charge and sustain the metallic pieces, originated inadequate postures of workers in the welding process, and this increased up to 75% the number of employees in this area, with visits to the doctor of the company where the investigation was made, and visits to the Mexican hospitals located in the city of Mexicali. In addition, it caused that some people failed to his job for a few days, and in certain employees not work and need visit the Mexican health institutions. This caused extra costs to the company due to this situation, and originating a rotation of personnel in manufacturing area evaluated, generating errors, which caused concern in the supervisory staff and managers of this evaluated industrial plant (Joan Burton, 2010). The concern was greater when certain aluminum frames arrived at the places where were used in the private residential with dimensions uneven, and it was a problem in the construction of homes. The health symptoms in workers caused two concerned diseases as cervicalgia and epicondylitis that generated an inability of workers, being a high risk in the workers of the manufacturing area analyzed. The information of the industry, and was correlated with information of data from visits to the medical institutions and records of health institutions in Mexicali.

Health symptoms generated in the industry

In the field of occupational health in the industry, five health symptoms may occur due to efforts of various bodily areas and poor postures, when developing the activities of an industrial process. The health symptoms that reveal the presence of diseases are dosalgia, cevicalgia, kyphosis, torticolis and epicondylitis. In the investigation was made, with cervicalgia was occurred with more frequency, due to the great efforts of lifting, loading and holding activities of the metal parts for the gluing operations of the aluminum window frames of the analyzed industry (María Loreto DíazJ., 2014; Yunus Dogramaci et al, 2009). The metal parts that were moved from one place to another by the workers, have a weight of 20 kilograms, and it with the repetitive process generated fatigue and later discomfort and even some workers were discomforted by the health symptoms. The other disease observed in this study was epicondylitis. The year 2017, were presented the most severe period of the cervicalgia symptom, with the highest number of cases with 1230 cases, followed by 2018 with 1158 cases and 2019 with 1093. As a reference, in 2017, 66% of the 100 people evaluated presented the cervicalgia symptom, while 52% had epicondylitis and 36% of workers presented both diseases.

2. Methodology

The analysis was made in groups of 10 people, to evaluate the movements of the workers and observe at each stage of the activity, if any health symptoms were present of discomfort or pain in the persons of the operations of this

manufacturing process. The evaluation periods were in 30-minute period, analyzing in detail each movement of the workers and stopping the activities when observing something that had a negative effect on their health. The analyses were at the hour, daily, weekly, monthly, annual and seasonal levels from 2017 to 2019. Once the activity of the workers a new proposal was developed that is in development of an automated exoskeleton system for the support of the lifting operations, loading and holding metal parts. This was to avoid the presence of the health symptoms mentioned above, that appeared in the workers in this investigation in the metallic industry evaluated, due to overstrain and repetitiveness of the operations

3. Results

In the investigation was made, it was observed that in the elaboration of industrial activities, even though they were of little weight of the metallic frames, generated mild health symptoms and sometimes was presented a serious way in the workers of the manufacturing areas analyzed. The main cause of the occurrence of the diseases presented was due to the repetitiveness of the operations, and it was generated a fatigue until the discomfort and pain.

Analysis of diseases in manufacturing processes

The evaluations prepared reflected the indices of the two diseases that were presented in this investigation, as observed in Tables 1, 2 and 3; indicating the average percentages per month of the three years analyzed.

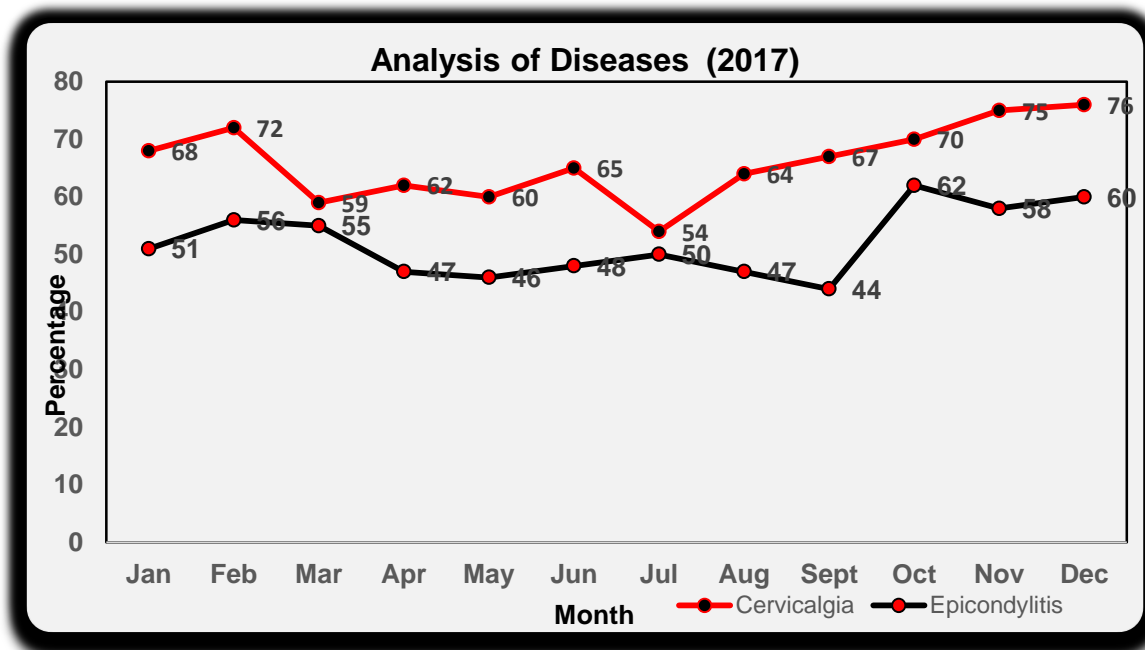


Fig.1 Occurrence of diseases (%) in 2017 of the manufacturing area

The figures 1, 2 and 3 shows the percentage indexes of the diseases occurred monthly, in the three years evaluated, and indicated that the health symptoms were higher in 2017, but when was applied the adequate ergonomic methods, in the begin of 2018, was decreased the health symptoms in 2018 and 2019, essentially in the disease of cervicalgia.

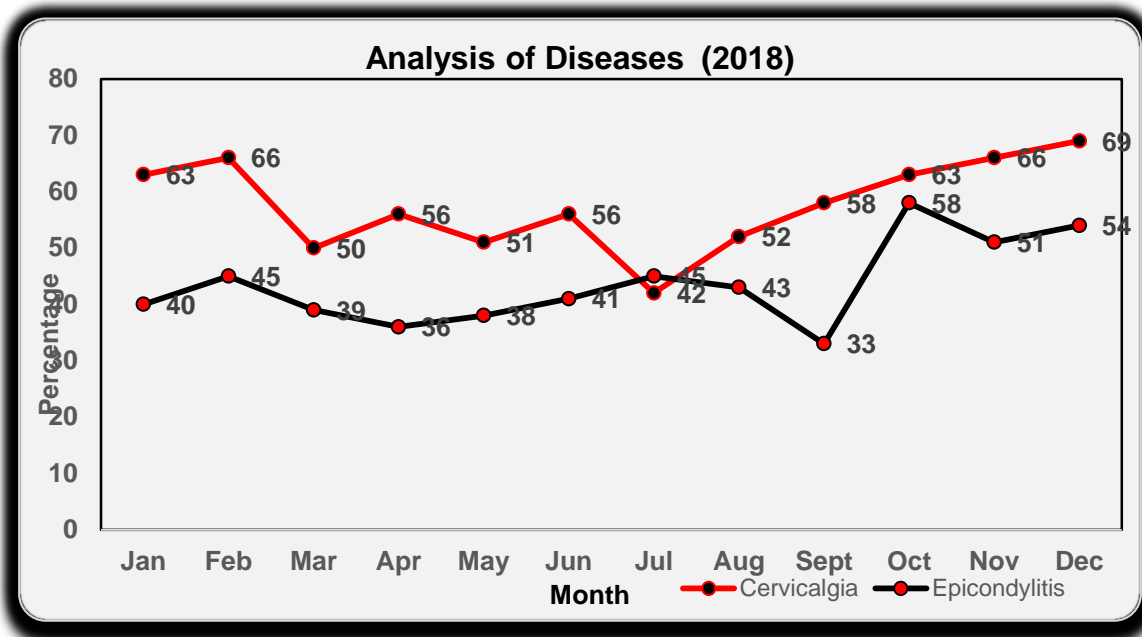


Fig.2 Occurrence of diseases (%) in 2018 of the manufacturing area

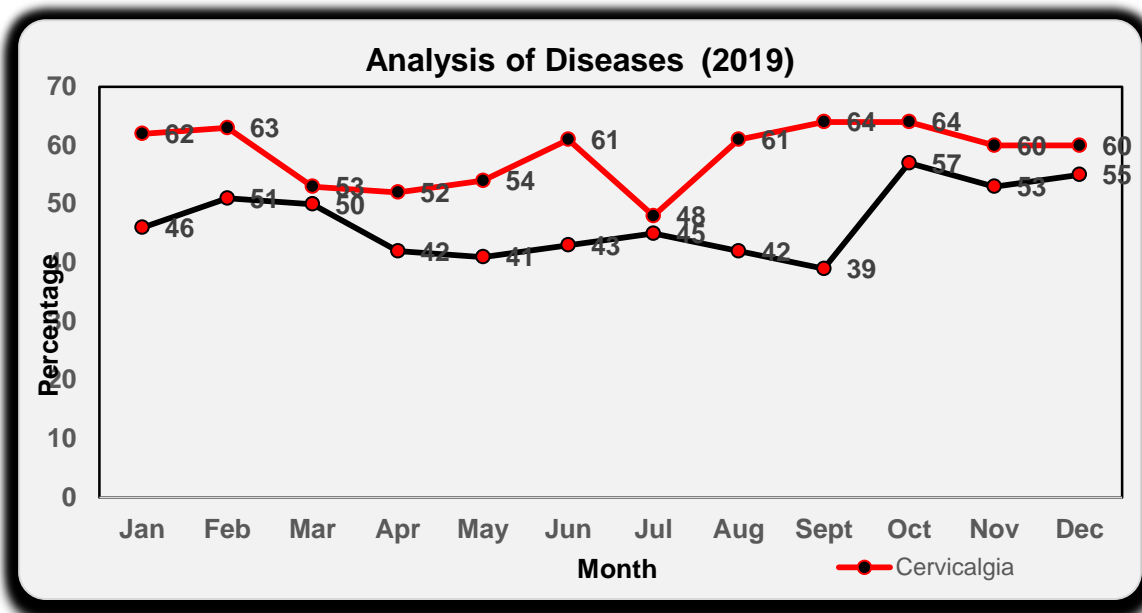


Fig.3 Occurrence of diseases (%) in 2019 of the manufacturing area

The same process occurred with the symptom of epicondylitis, with the highest index in 2017, decreased in 2018 and 2019. The presence of cervicalgia and epicondylitis more frequently in 2017 caused an increase of the visits to the company doctor and health institutions in Mexico, staff turnover and human errors in the operations of the manufacturing area. It was observed that the average in 2017 of cervicalgia was 66% and 52% of epicondylitis, as well as in 2018 it was 62% and 47% and for 2019 58% and 44% respectively. From the beginning of the investigation, the supervisory and management personnel were informed of what was happening with the workers, but it was until the begin of 2018, that the decision was made to act with respect to what happened to the

production workers of the business. The late reaction caused fines from the health sector of the Mexican Republic and labor demands from the operational staff that had been working for years, generating large expenses for these legal actions. The study was very useful to minimize negative effects on health of workers, with it the legal actions.

Evaluation of diseases and costs

The evaluation of costs for dorsal diseases in the industry, was based on the percentages obtained from the occurrence of the two diseases analyzed, with an evaluation of the costs generated by human errors and what caused by loss of customers for not delivering the products on time was carried out. According to the managerial staff, in the first year of the investigation period, five clients were lost and 50% of the sales were generated, so the study supported into recovering them in early 2018, when was checked the occurrence of the dorsal diseases and was presented the improvement to avoid these worrisome symptoms. Table 1 shows the correlation evaluation of the errors by workers occurred in the manufacturing area where was made the investigation, the time of rework and costs of the company by each 10 workers evaluated. The monthly analysis, showed in this table, the errors caused by pain discomfort in neck shoulders and back of workers with the average of 490 cases, related with the time of rework with 7455 minutes as a standard time, causing costs for this action, of average of 310625 dollars by each 10 workers in 2017. This worried to personnel of management, supervision and technical people of this industry where was made the investigation.

Table 1. Analysis of errors and costs (2017)

MONTH	HUMAN ERRORS BY DORSAL DISEASES	TIME OF REWORK (minutes by each 10 workers)	COSTS (Dollar by each 10 workers)
January	536	7350	306250
February	518	6990	291250
March	489	7560	315000
April	477	7320	305000
May	465	6900	287500
June	434	8010	333750
July	449	6570	273750
August	468	8400	359000
September	485	8160	347000
October	493	7800	328500
November	522	7470	311250
December	548	6930	288750

Climate effect on body diseases in the industry

The climate was an important factor in the generation of the health symptoms presented in the workers of the evaluated manufacturing area of the analyzed metalworking industry, as shown in Tables 2 and 3. This aspect was

evaluated because in the summer months, workers sometimes were in front of air conditioning and with the movements of the activities in the manufacturing area, generated heat in its body and this caused some pain discomfort. Then, in sometimes workers were some part of back a little uncovered, and originated several health symptoms mentioned above, especially in the back and spine. This is illustrated in the table 2 (from May to August of 2018), and in the months of winter analyzed, that is represented in table 3 (from November of 2017 to February of 2018). The movements of the operations in this manufacturing area, caused heat in their body and sometimes the operators of the industrial process evaluated, take off their jackets and winter clothes, generating a pain discomfort and several symptoms in the back, as in the summer analysis.

Table 2. Correlation of climate and generation of dorsal diseases (May to August 2019)

MONTH	AVERAGE TEMPERATURE, °C	AVERAGE RELATIVE HUMIDITY, %	DORSAL DISEASES
May	32	45	27
June	38	49	30
July	41	53	33
August	43	57	36

Table 3. Correlation of climate and generation of dorsal diseases (November 2018 to February 2019)

MONTH	AVERAGE TEMPERATURE, °C	AVERAGE RELATIVE HUMIDITY, %	DORSAL DISEASES
November	24	58	32
December	19	63	37
January	13	69	41
February	21	72	44

Consequences of dorsal diseases

Some workers were suffering of dorsal diseases after develop the activities in the production area evaluated and were necessary use an abdominal girdle to support a little the pain discomfort. This industry provided to the operators that needed this abdominal girdle, and increase its costs of the manufacturing process. Also some workers visited some Mexican health institutions and were checked its progress in the recovery of health for the symptoms mentioned above. This abdominal girdle was a cost of 45\$ and was used by 40 workers of this industry.

Table 4. Correlation of dorsal diseases and costs (2017-2019)

YEAR	Costs presented in the industry, \$	Costs presented in the health intuitions, \$
2017	310,625	478,910
2018	224,279	367,345
2019	178,564	278,346

The table 4 represents the costs of any year from 2017 to 2019, about the of which the industry evaluated, dedicated as payment for visits to the doctor within the company, as well as for errors of new workers in the evaluated manufacturing area and for lack of delivery to the client in the established period. In addition, the cost of fines generated when the workers of the evaluated company visited the public health institutions of Mexico and for disabilities is resulted for each group of 10 workers.

Automated Exoskeleton Proposal

The results obtained, generated a proposal of an automated system was developed based on the structure of an exoskeleton as shown in Figure 4 as a block diagram and that now is working with the design of the exoskeleton system with a mathematical simulation and procedure of make the fabrication of it, to support to workers of this industry evaluated. The block diagram is in figure 4.

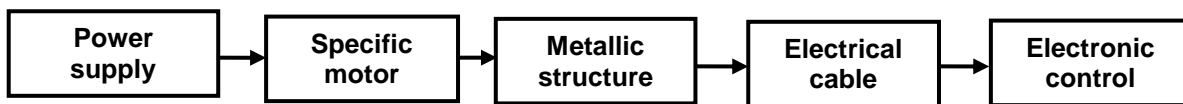


Fig.4 Block diagram of the exoskeleton system to support to workers.

The block diagram consists of five steps that are explained subsequently:

- a) *Power supply.* Is for provide the electrical energy with 120 volts of voltage and 1 Amperes of electrical current, that is necessary to function the exoskeleton system, with a converter of 120 volts to 12 volts, to use the adequate motor of the next step.
- b) *Specific motor.* Is a motor with 12 volts and 1 Amp of maximum electrical current, but was used normally 0.25 Amperes to not force the movements of workers and not generate a several pain discomfort.
- c) *Metallic structure.* Is used the correctly structure to support the neck, shoulder and back of the worker. Is made from aluminum to be a light structure and not disturb the movements of the personal of the manufacturing area analyzed.
- d) *Electrical cable.* Is used the adequate electrical cable to low voltage (12 volts) and electrical current (0.25 Amperes).
- e) *Electronic control.* Has the hardware and software required in the movements of the exoskeleton system to support to the workers and not suffer some dorsal diseases.

Numerical analysis of the proposed exoskeleton system

The proposed system consists of an engine weighing no more than 10 kilograms with a mechanical power of 25 watts that supports the lifting, loading and sustaining activities of the metal parts of the manufactured window frames. This potency factor is resulted from the next mathematical procedure:

$$W = M \text{ (Nm) } \times w \text{ (rad/s)} \quad (1)$$

$$W = 16.4 \text{ Nm (dato del par a máximo rendimiento; Nm) } * (\text{Velocidad a máximo rendimiento; rad/s})$$

Mathematical procedure

$$15 \text{ rpm} = 15 \cdot (1 \text{ revolution}) / \text{min} \times (1 \text{ min}) / (60 \text{ s}) \cdot (2\pi \text{ rad}) / (1 \text{ revolution}) = (10 \cdot 2 \cdot \pi) / 60 = 1.57 \text{ rad/s}$$

$$W = (16.4 \text{ Nm}) \cdot (1.57) \text{ rad/s} = 25 \text{ Watts}$$

Table 5. Estimated analysis of errors and costs with the exoskeleton (2020)

MONTH	HUMAN ERRORS BY DORSAL DISEASES	TIME OF REWORK (minutes by each 10 workers)	COSTS (Dollar by each 10 workers)
January	54	1086	87456
February	53	978	88324
March	46	965	92123
April	42	1010	88823
May	45	899	87824
June	39	856	79690
July	44	847	70245
August	46	940	78923
September	42	969	84567
October	43	1011	94678
November	48	990	87896
December	52	945	89023

In table 5, is presented an estimation of the human errors, time of rework and costs to 2020, using a mathematical simulation, when is considered utilize the exoskeleton, observed that is reduced in the three factors evaluated.

4. Conclusions

The prevention of dorsal diseases in industrial operations is of great importance to avoid risk situations in workers of the metallic industry as the evaluation presented in this investigation in an industrial plant installed in the Mexicali considered as a desert city. In this analysis occurred the presence of two dorsal diseases, where cervicalgia was the principal symptom occurred with more frequency and the second disease was considered the epicondylitis with a lower range than the principal disease, with a high risk of suffer of the workers evaluated in this scientific study. This generated concern in the management and supervision staff, due to the increases in staff turnover that led to an increase in human errors, which had a negative effect on manufactured products by generating rework costs and losing customers due to late delivery to the customer.

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