



## Analysis of Musculoskeletal Injuries in the Welding Process in an Electronic Industry of Mexicali, Mexico

Pedro Alberto Escárcega Zepeda<sup>1</sup>, Yanet Villarreal Gonzalez<sup>2</sup>, Carlos Raúl Navarro Gonzsalez<sup>3</sup>, Rigoberto Zamora Alarcon<sup>1</sup>, Gustavo López Badilla<sup>4</sup>

<sup>1</sup>*Departamento de Ingeniería Industrial–Metal Mecánica, Tecnológico Nacional de Mexico, Instituto Tecnológico de Mexicali, Mexicali, Baja California, Mexico.*

<sup>2</sup>*Departamento de Metal Mecánica, Tecnológico Nacional de Mexico, Instituto Tecnológico de Mexicali, Mexicali, Baja California, Mexico.*

<sup>3</sup>*Departamento de Ingeniería Industrial, Facultad de Ingeniería, Universidad Autonoma de Baja California, Mexicali, Baja California, México.*

<sup>4</sup>*Departamento de Ciencias Básicas, Instituto Internacional de Desarrollo Empresarial–INIDE, Tijuana, Baja California, México.*

**Abstract** – This investigation in the ergonomics area of the occupational health issue arises when there were cases of musculoskeletal injuries in an electronics sector industry located in the city of Mexicali, which is an arid area in the northeast of the Mexican Republic. A detailed analysis of the industrial operations was developed, especially the area of welding in manufacturing production lines, and the way how musculoskeletal injuries occurred. It was observed that even with the appropriate method used in the training process for new operating personnel without experience in welding operations of electronic components in electronic products manufactured in the company where the scientific study was made, it was determined that the operators of this specific area, tend to perform their functions without control of the proper working method. This generated the discomfort at the time of elaborating the activities of part of the operative personnel and later the musculoskeletal injuries. Workers with experience in this type of operation were also evaluated and still performed the operations as they felt more comfortable, but this caused the injuries. The information on the occurrence of cases of this type of event included an evaluation from January 2020 to December 2020, with indicators that represent an increase of 40% in cases of this type of health symptom.

**Keywords:** Ergonomy, musculoskeletal injuries, welding process, electronic industry, overheat.

### 1. INTRODUCTION

Musculoskeletal lesions are generated by the elaboration of activities inadequately or repetitively, which cause some kind of discomfort in an initial period of the presence of this health symptom and can then originate sometimes, until the loss of movement of some Type of muscle, tendon or upper and lower extremities (Ortiz or, 2013). This type of injury is sometimes generated by not having the appropriate tool, as well as the working methods and lack of awareness of workers in the operative area. The sections of higher incidence of this type of symptom are hands, arms, shoulders, back, column, legs and feet, essentially; where muscles, tendons, bones, ligaments and intervertebral discs are affected (Pardo, NA, 2010). This type of occurrence in industries from various sectors is being served since 2000 more frequently, due to the large



number of disabilities Labor that occurred in the various types of industrial processes (Navarro González CR et al., 2021).

## 1.1 Skeletal muscle injuries

In this investigation, these relevant health symptoms were presented in certain parts of human body due to some repetitive or poorly elaborate activities. This occurs more frequently in industrial plants, due to the great stress that is presented by being in manufacturing areas where industrial processes occasionally at high speed (Navarro González C. R. et al., 2019). These situations are elaborated in this way by the incorrect sometimes planning of logistics, managerial, managerial, copse, warehouse, sales and finance; In its daily meetings at the beginning of each working day. This type of injuries presented in arms, years, shoulders, column, back, legs and feet; It is very common in the electronics industry located in the city of Mexicali. Sometimes, musculoskeletal lesions, are presented at the time of developing the activities of industrial processes and on other occasions can be presented in future periods. Musculoskeletal lesions can be presented as bone fractures, as well as joint dislocations, sprains, distention, ligament tears and lacerations of tendons (Yunus D. et al., 2009, Navarro González C. R. et al., 2020).

## 1.2 Electronic Industry in Mexicali

In Mexico there are a large number of companies in the electronics sector, which are installed in industrial parks from the most important cities such as Mexico City, Guadalajara and Monterrey and in some popular border cities with USA as is Mexicali, Tijuana, Nogales, Juarez and Reynosa cities (López G et al., 2019). In Mexicali, the highest percentage of companies (75%) are from the electronics industry or is dedicated to the manufacture of electronic products, with a variety of manual and automated industrial processes, where great stress is generated by speed at the Operating each stage of manufacturing. In this type of industry, some types of injuries mentioned in the previous section are presented, the most common being presented at anos, arms and shoulders. According to some specialists, the highest incidence processes are the welding processes, due to the considerable amount of repetitive movements and by being in contact with temperature levels greater than 50 ° C generated by the captain to elaborate the welding process (López BG and Col., 2007).

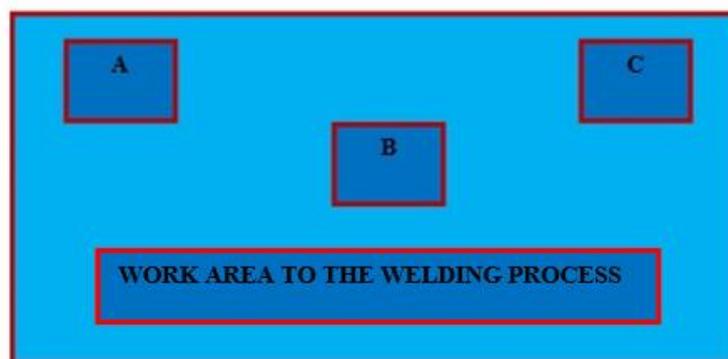
## 1.3 Industrial processes in the Mexicali electronics industry

In the electronic industry there are different industrial processes where the common ace is the linear type or also called a continuous process, taking advantage of that it goes in a straight line, the programmers of the planning of the products to be manufactured, generate high-speed activities (López BG et al., 2010). In addition, of this type of industrial process, they have operations in groups attached to the production line in calls manufacturing cells, where the welding processes are developed. In this type of manufacturing area, an adequate organization must be had adequate for the types of linear and lateral movements that must be done, as well as not having the years very close to the captain for welding with the aim of avoiding the constant heating of the years They cause damage to the joints or part of the nervous system (Ortiz O., 2013). Then it is observed in Figure 1, the way in which the welding process is performed.



**Fig -1:** Process of welding activity using a captain.

In the above figure it is represented how the captain is taken for welding process, showing the thumb in a part of the iron to direct the welding operation and the other hand of the hand taking the captain to sustain it and achieve a balance for the welding process. Figure 2 presents a form of organization of the equipment and tools used at a table where the welding process is prepared, in an industrial operation called Manufacturing Cell.



**Fig -2:** Worktable organization for processing process with (A) Iron equipment base, (b) tin welding and (c) electronic devices to weld

Source Investigation analysis

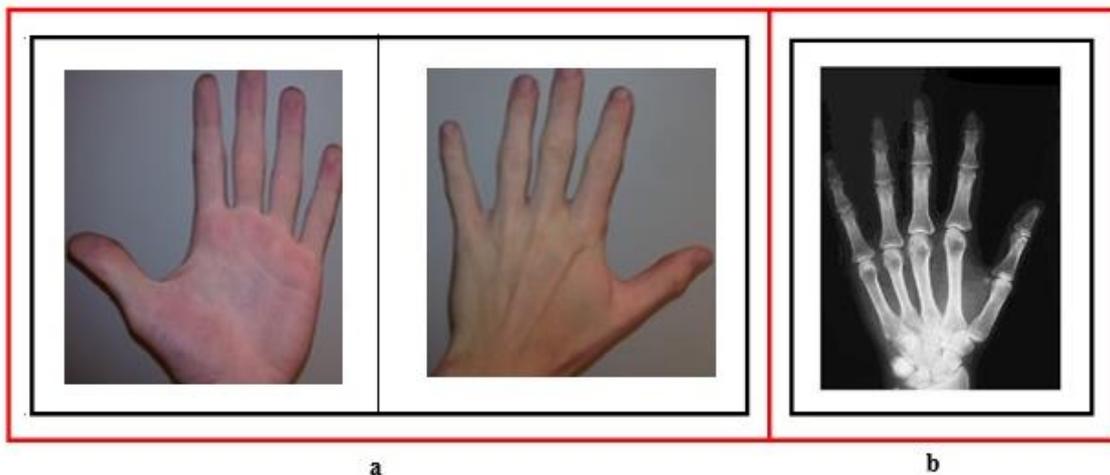
The above figure shows the organization of the work table where a person in the manufacturing operating area, observing that the three zones with the curtain base with a dimension of 90 square centimeters, the location of tin welding with a dimension of 120 square centimeters and finally the placement in a plastic box of electronic devices to weld with a dimension of 160 square centimeters. The Bureau has a dimension of 200 linear centimeters per 100 linear centimeters (20,000 square centimeters) of area, being considered by manufacturing specialists, but not from ergonomics specialists. The process of welding operation activity is shown in Figure 3, and illustrates that the anus is exposed to the temperature of the captain, which can be caused by damage in prolonged periods of this exposure, in the joints, bones and nervous system. Another aspect of importance was the intensity of lighting, with which it was detected that it influenced the process of operation and quality of the prepared by-product, by making errors of the

welding activity with electronic devices attached to the electronic boards. Even though the sense of sight, a health symptom situation was generated in the operative personnel of this area of manufacturing, this problematic situation is treated in the other integrating activity, and only is dedicated in this integrating activity to health symptoms in hands.



**Fig -3:** Inadequate welding activity process  
Source Investigation analysis

The above figure represents an incorrect way of carrying the captain at the time of elaborating the welding process, generating at least slight discomfort in hand, until serious injuries. Next, the parts of a hand and an x-ray of a hand are shown. It is observed that the captain is taken incorrectly, being able to cause a symptom of health.



**Fig -4:** Parts of the anus: (A) Shovel and back and (b) X-ray

Source (a) <https://wikipedia.org/wiki/mano#/media/archivo:lefthand0jpg>

(b) <https://www.elsevier.es/es-revista-medicin-integral-63-articulo-las-lesions-mano-urgences-13022435>

The previous figure has the two ends of the hand (palm and back) and an x-ray indicating that it can generate health symptoms for some damage to skin, joints, bones and nervous system.



**Fig -5:** Hand with damage to leather and articulation by using in the soldering process for long periods of time.

Source Investigation analysis

The above figure illustrates an aid damaged by the use of a person operative person's g that works in the soldering process of the manufacturing area, observing a wear on the skin and possibly in joints by not being able to completely close the year in the form of a fist.

## 2. METHODOLOGY

The investigation was made in four stages to achieve the maximum amount of numerical information of the variables involved:

- a) Analysis of observation and registration of numerical information. It was elaborated to elaborate obtaining quantitative information through observations, and taking readings and a timer and being represented in tables to perform statistical analyzes.
- b) Evaluation of numerical information. It was performed based on the information obtained from the previous stage with the Excel program, obtaining tables and graphs.
- c) Development of continuous improvement. An improvement was made with the forearm placement area, use of gloves with free fingers and in the organization of materials and welding equipment.
- d) Analysis of elaborate improvement. It was elaborated to evaluate the improvements made and thereby determine the impact of the development of such improvements.

## 3. RESULTS

The analyzes prepared represent the presence of health symptoms in the hands due to the process of soldering electronic components on electronic boards and the effects of the development of the improvements mentioned in the methodology section. The following sections illustrate the relevant results obtained in this investigation.

### Correlation analysis of health and working conditions

A correlation analysis of health symptoms and working conditions is showed in Table 1.

**Table -1:** Correlation of health symptoms in welding process (2020)



Causes	T, °C	HR, %	CA, ppm	L, luxes
Consequences				
Mild discomfort in the hands	72	49	38	32
Severe discomfort in the hands	75	53	43	38
Inmovility in hands	79	55	4	40

T. Temperature, HR. Relative humidity, ca. Air contaminants (SO<sub>2</sub>, NO<sub>x</sub>, CO, O<sub>3</sub>), L. Luminosity

The correlation analysis was prepared by obtaining numerical data from schedules, daily, weekly, monthly, seasonal periods (spring, summer, autumn, winter) of the year 2020, number of movements of the welding process, climatic variables, luminous intensity and quantity of visits to the doctor inside and outside (IMSS, 2020) of the evaluated company. An evaluation of the times was developed in seconds, minutes, hours in the schedules, daily, weekly, monthly, seasonal, and of the year 2020, as shown immediately.

**1 minute = 60 seconds, 1 hour = 60 minutes = 3,600 seconds.**

The work schedule of a welding activity is 10 hours per day, from Monday to Friday, with a period of rest to consume food (from 10 am to 10:30 a.m.) and two periods of 15 minutes of rest Using the working gymnastics (2 x 15 minutes equals 30 minutes), working effectively 9 hours per day, being 45 hours a week, 180 hours Al is, (not counting Saturdays and Sundays and holidays, even when certain periods of the year you work these days as extra time) and 2160 hours a year, being 129,600 minutes and 7,776,000 seconds. These periods of time are considered to determine the degree of discomfort in the anus by the exposure of the high temperature of the captain at approximately 300 ° C. The iron used is Weller of 150 ° C to 450 ° C. Also, an analysis of medical visits was held within and exterior of the electronic industry evaluated, with the aim of detecting periods of greatest incidence and determining the types of problematic situations and on it to develop the relevant improvements. Figure 6 is illustrated; the analysis is illustrated, where it is observed that the number of visits of greatest incidence was made within the evaluated company, followed by those carried out abroad by the company. Subsequently, the levels of mild discomfort in hand are shown, thus continuing with the frequency of cases of severe discomfort in hand and cases of immobility in hand. The correlation analysis was elaborated by obtaining numerical data of hourly, daily, weekly, monthly, seasonal periods (spring, summer, autumn, winter) of the year 2020, of the number of movements of the welding process, climatic variables, light intensity and quantity of visits to doctor inside and outside of the evaluated company (IMSS, 2020).

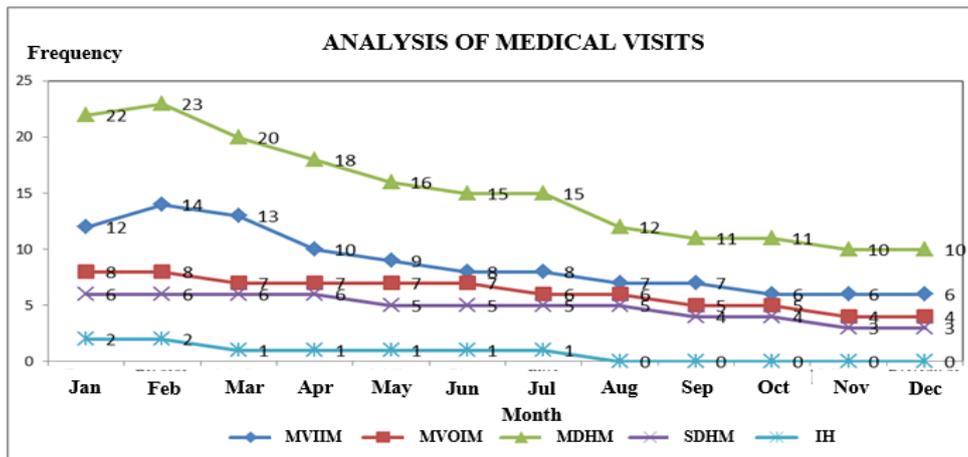


Fig -6: Analysis of medical visits of operating personnel of welding process (2020).

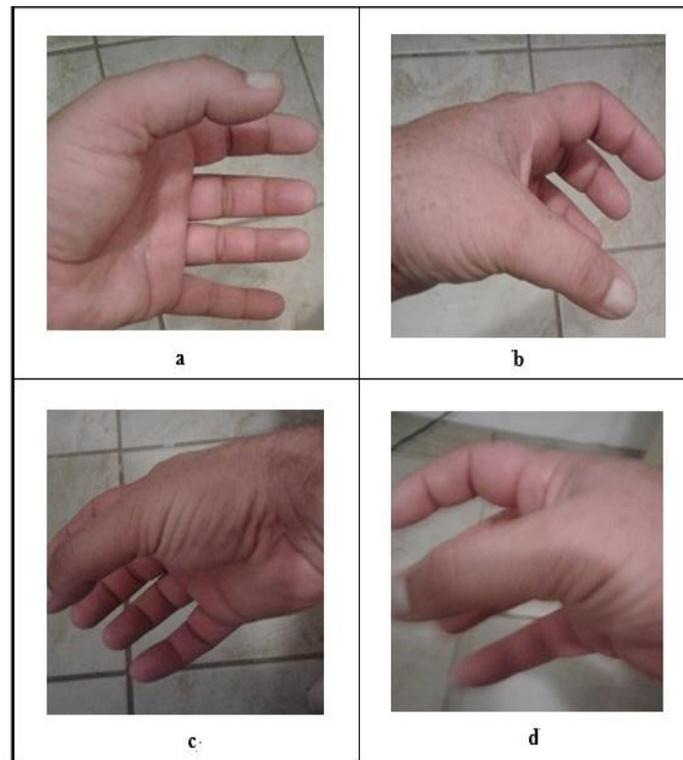
MVIIM. Medical Visits Inside of Industry at Month; MVOIM. Medical Visits Outside of Industry at Month; MDHM Mild Discomforts in Hands at Month; SDHM. Severe Discomfort in Hands at Month; IH Immobility in hands.

### 3.1 Welding process

Elaborated analyzes represented the presence of health symptoms in hands by the welding process of electronic components on electronic boards and the effects of the development of the improvements mentioned in the methodology section. The relevant results obtained in this investigation are illustrated in the following sections.

### 3.2 Analysis of health symptoms in hands

The process of welding in the manufacturing area of the industry evaluated, generated health symptoms in years of operational workers of the manufacturing cells of the production lines evaluated. Some representations of the discomfort in hands, are illustrated in Figure 7, with hands with cramping, and that they cannot be closed to form the Puno of the hand in a normal way. In this figure, it is observed that both the left and right hand present situations of wanting to close the hand as Puno and it is difficult for an operational worker that workers for 3 continuous years in the welding process area. The four representations illustrate the same situation with little mobility and a little inflamed their hands



**Fig -7:** Symptoms of health by use of captain in: (A) Left hand palm, (B) left hand back, (c) right hand palm, (d) back hand

### 3.3 Proposed changes feasible to be made

Based on problematic situations, three momentary improvements were developed and evaluations are still being carried out to avoid some symptom of health in hands. The three proposals for improvement are presented below:

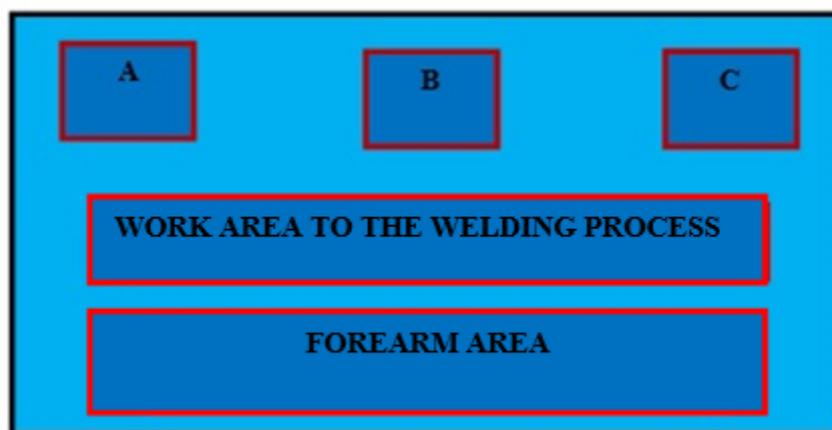
- a) A training program was carried out to inform operating personnel of the causes and consequences of not developing welding operations without the appropriate method and equipment. This program was developed in final periods of each turn (one hour a day for a period of two weeks), to avoid inference with the production goals.
- b) An analysis was developed with certain workers in the manufacturing area of the welding process, which have diverse annual periods, achieving the proposal to use biomechanical gloves such as those shown in Figure 8, representing an improvement in the reduction of visits to the doctor.
- c) the reorganization activity of the equipment and materials used in the work table of the welding process was developed, as well as an area to place the forearms to have a better comfort at the time of the activities in this area of manufacturing, being represented In Figure 9.



**Fig -8:**Hands with work gloves

Fuente:[https://www.amazon.com.mx/Kagogo-Taekwondo-Entrenamiento-Manoplas-Sparring/dp/B06XCTM9DZ/ref=asc\\_df\\_B06XCTM9DZ/?tag=gledskshopmx-20&linkCode=df0&hvadid=547266555061&hvpos=&hvnetw=g&hvrand=13356681356564128438&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=1010154&hvtargid=pla-350108794464&psc=1](https://www.amazon.com.mx/Kagogo-Taekwondo-Entrenamiento-Manoplas-Sparring/dp/B06XCTM9DZ/ref=asc_df_B06XCTM9DZ/?tag=gledskshopmx-20&linkCode=df0&hvadid=547266555061&hvpos=&hvnetw=g&hvrand=13356681356564128438&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=1010154&hvtargid=pla-350108794464&psc=1)

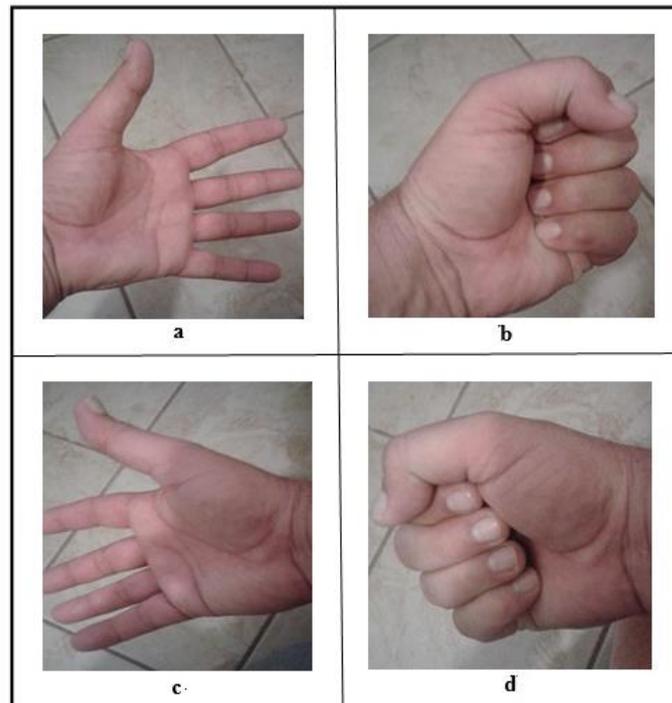
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**Fig -9:**Improvement in the organization of work improvement for process DEN Welding with (A) CAUTÍA equipment base, (b) Tin welding and (c) Electronic devices to weld

### 3.4 Continuous improvement and expected impact.

With the developed improvements it was possible to evaluate from the month of April to December 2020 to workers of the welding process, being represented in Figure 10, where it is observed that the hands have greater mobility, reducing the symptoms of health and with it the visits to the doctor.



**Fig -10:** Representatives of hands of operating personnel that used iron to the welding processes: (a) Left hand palm, (b) Fist of left hand, (c) right hand palm, (d) Fist of right hand

#### 4. CONCLUSIONS

The investigation developed in an electronic industry located in Mexicali City, represents an analysis that relevantly describes the generation of health symptoms in hands, evaluating operations in industrial processes, essentially in the welding activity, where movements were presented and A higher temperature than normal in the welding captín, without being regulated, and also noting that the visits were increased to the physician within the exterior of the evaluated company. Once the investigation has started, improvements were made, which supported improvements in the working tables of the welding activity and thereby reducing both health symptoms in hands, such as visits to the indoor and exterior doctor of the industry evaluated. After developing the improvements, they were evaluated to determine if they were generating adequate operation and thus observing whether they could be optimized and with avoiding health symptoms in hands, before carrying out the investigation. With this analysis, both productivity quality increased its levels of the manufactured products in the evaluated industrial company.

#### REFERENCES

- [1] IMSS - Instituto Mexicano del Seguro Social. (2020). Memoria Estadística en México: Coordinación de Salud en el Trabajo; Reporte del IMSS.
- [2] López, G., Tiznado, H., Soto, G., De la Cruz, W., Valdez, B., Schorr, M., Zlatev, R. (2010). Corrosión de dispositivos electrónicos por contaminación atmosférica en interiores de plantas de ambientes áridos y marinos; Nova Scientia, No. 5. Vol. 3(1). ISSN 2007-0705.



- [3] López, B. G., Valdez, S. B., Schorr, W. M., Tiznado, V. H., Soto, H. G. (2010). Influence of climate factors on copper corrosion in electronic equipments and devices, *Anti-Corrosion Methods and Materials*, Vol. 57. Issue 3. pp 148–152.
- [4] López B.G., Valdez B., Zlatev R. Flores J., Carrillo M, Schorr M. (2007). Corrosion of metals at indoor conditions in the electronics manufacturing industry, *Anti-Corrosion Methods and Materials*, Vol. 54 No. 6, pp. 354–359.
- [5] Navarro González, C. R., Villarreal González, Y., Escárcega Zepeda, P. A., Sánchez Corona, A. L., Arredondo Robledo V. Montoya Reyes, M. I., Mora Moreno, E., Samaniego Ramos, M. G., Vargas Bernal O. Y., Mendoza Muñoz, I. (2020). Analysis of Ergonomic Methods used to Prevent Negative Effect in the Health of Workers in a Metallic Industry in Mexicali, Mexico, *Mediterranean Journal of Basic and Applied Sciences (MJBAS)* Volume 4, Issue 3, Pages 33–41, July–September 2020.
- [6] Navarro González, C. R., Montoya Reyes, M. I., Jacobo Galicia, G., Mendoza Muñoz I. (2019). A Metalearning Approach on Sociotechnical Systems Toward Improving Organizational Effectiveness, *Book Chapter*, IGI Global, 1–14.
- [7] Navarro González, C. R., Villarreal González, Y., Escárcega Zepeda, P. A., Sánchez Corona, A. L., López Hernández J. G., Arredondo Robledo V., Romero Samaniego E., Mendoza Muñoz, I. (2020). Analysis of Ergonomic Methods used to Prevent Negative Effect in the Health of Workers in a Metallic Industry in Mexicali, Mexico, *Mediterranean Journal of Basic and Applied Sciences (MJBAS)* Volume 4, Issue 3, Pages 33–41, July–September 2020.
- [8] Ortiz, O. (2013). Factores de riesgo de trastornos músculo-esqueléticos crónicos laborales; *Medicina Interna de México* Vol. 29, No.4, Julio–Agosto, 2013, 47–56.
- [9] Pardo, N. A. (2010). Prevalencia de síntomas osteomusculares y factores asociados en los embaladores de leche de una pasteurizadora en Neumocón, Cundinamarca [en línea]. *Rev Col Enf.*, 2010; Vol. 5, No 5, 23–42.
- [10] Yunus, D., Aydiner, K., Nazan S., Gokhan D., Nedim Y. (2009). Treatment of lateral epicondylitis using three different local injection modalities: a randomized prospective clinical trial; *Archives of Orthopedic and Trauma Surgery* Volume 129, pp.1409–1414.