Article **Journal of Engineering Applications**

December 2021, Vol.8 No.26 14-26

Analysis of postural geometric ergonomic risks and their impact on the productivity of manufacturing industry workers

Análisis de riesgos ergonómicos geométricos posturales y su incidencia en la productividad de trabajadores de la industria manufacturera

MUÑOZ-HERNANDEZ, Raquel†* & RANGEL-LARA, Saúl

Universidad Politécnica del Valle de México, Industrial Engineering Management. Mexico.

ID 1st Author: *Raquel, Muñoz-Hernández* / **ORC ID:** 0000-0002-4461-8027, **Researcher ID Thomson:** I-6661-2018, **arXiv ID Author:** Raquel4, **CVU CONACYT ID:** 1001913

ID 1st Co-author**:** *Saul, Rangel Lara* / **ORC ID:** 0000-0003-1498-340X, **arXiv ID Author:** Dr.SaulRangel, **CVU CONACYT ID:** 103670

DOI: 10.35429/JEA.2021.26.8.14.26 Received: July 30, 2021; Accepted: December 30, 2021

Abstract

Currently, technological changes and innovations are very dizzying, which also implies a constant update in work systems. The case addressed is a manufacturing company where the staff has increased disabilities and absences with the change of product; they claim to have had accidents due to pain in the shoulders, arms, legs and / or back. This has had an impact on health, productivity and profits. The objective of the present study was to identify if the conditions of the job and the procedures favor the presence of occupational diseases DTA's (Cumulative Traumatic Disorder), in the operators; as well as studying the behavior of risk factors associated with inappropriate postures, handling loads and their interrelation to determine the effect on the health of exposed workers and their incidence on productivity. The applied methodology was an analysis of the Work Station in reference to the Anthropometry and Goniometry of the angular movements of two representative workers of the use of tools and load handling respectively. The Ergonomic methods applied were the RULA Method for postures and flexions giving a value of 7 (Maximum) and FCD for lifting a value of 3 (Maximum). The results indicated high risk for the two workers with the need for a redesign of the work station and the procedures to preserve the health of the workers since there are threats of deterioration both of a psychosocial and physical nature. It is necessary to establish an Ergonomic Plan of preventive action with emphasis on biomechanical and environmental factors.

Work station, DTA's, Risk

Resumen

Actualmente los cambios tecnológicos e innovaciones son muy vertiginosos lo cual implica también una constante actualización en sistemas de trabajo. El caso abordado es una empresa manufacturera donde el personal, ha incrementado las incapacidades e inasistencias con el cambio de producto; ellos manifiestan haber tenido accidentes debido al dolor de hombros, brazos, piernas y/o espalda. Esto ha repercutido, en salud, productividad y utilidades. El objetivo del presente estudio fue identificar si las condiciones del puesto de trabajo y los procedimientos, favorecen la presencia de enfermedades profesionales DTA´S (Desorden Traumático Acumulativo), en los operarios; así como estudiar el comportamiento de factores de riesgo asociadas a las posturas inadecuadas, la manipulación de cargas y su interrelación para determinar el efecto en la salud de los trabajadores expuestos y su incidencia en la productividad. La metodología aplicada fue un análisis de la Estación de trabajo en referencia a la Antropometria y Goniometría de los movimientos angulares de dos trabajadores representativos del uso de herramientas y manejo de cargas respectivamente. Los métodos Ergonómicos aplicados fueron el Método RULA para posturas y flexiones dando un valor de 7 (Máximo) y FCD para levantamientos valor de 3 (Máximo). Los resultados indicaron riesgo alto para los dos trabajadores con la necesidad de un rediseño de estación de trabajo y de los procedimientos para preservar la salud de los trabajadores ya que existen amenazas de deterioro tanto de naturaleza psicosocial como física. Es necesario establecer un Plan Ergonomico de acción preventivo con enfásis en factores biomecánicos y ambientales.

Estación de trabajo, DTA’s, Riesgo

Citation: MUÑOZ-HERNANDEZ, Raquel & RANGEL-LARA, Saúl. Analysis of postural geometric ergonomic risks and their impact on the productivity of manufacturing industry workers. Journal of Engineering Applications. 2021. 8-26:14-26.

* Correspondence of the Author (Email: raquel.munoz@upvm.edu.mx)
† Researcher contributing as first author.

Introduction

Research leads to the generation of knowledge and this in turn to the transformation of society, through innovation and the use of new technologies or new applications of the same. The versatility of the media generates great accessibility and dynamism in the productive systems, in such a way that it is possible to have access to practically everything related to the implementation and continuity of productive and service companies.

Innovation and Technology have had such great advances that it is necessary to adapt the labor relations and consequently those of Safety and Health that govern these relations in order to maintain the harmony between the people that integrate them; considering as a priority point the protection of the physical and emotional integrity of the worker.

Due to the great growth of companies worldwide of all types of items, policies and controls in recent years regarding the prevention of occupational hazards, accidents and occupational diseases worldwide, have taken boom because the International Labor Organization (ILO. 2013). (and the World Health Organization (ILO. 2014). Because they show alarming figures of accidents, occupational diseases and deaths in their annual reports.

Preventive culture is the set of ideas, values, attitudes, ways of life, expressed in stable patterns of behavior within a society, so that they help to guide, order, promote a desired and expected behavior among its members on how the organization perceives the occupational risk, its consequences and how to deal with it.

It includes the implementation of preventive policies, their execution, evaluation and even modification. (Méndez, E., Figueredo, C., Chirinos, E., Goyo, A. & Rivero, R. 2011).

There are relevant factors that can be a cause of risk such as: the organization and content of work, the length of the working day, remuneration, ergonomics, and psychological pressure. Risks at work are the consequence of the conditions in which work is carried out; work and health deterioration are no longer considered inseparable dimensions.

Prevention means acting on the source or origin of the risk, so that work and deterioration of health are no longer synonymous.

In Mexico, based on the Political Constitution of the United Mexican States and the Federal Labor Law (LFT), the Ministry of Labor and Social Welfare (STPS) is the body that establishes the mechanisms (Laws, Regulations, Standards, among others) through which labor relations and Health and Safety will be governed, as well as keeping them updated according to the needs of society and monitoring compliance with them to ensure the balance of the factors of production.

On November 13, 2014, the Federal Regulation of Safety and Health at Work was published in the Official Gazette of the Federation (DOF, 2014), which came into force on February 13, 2015. The same abrogated the Federal Regulation on Safety, Hygiene and Work Environment of January 21, 1997.

The purpose of the regulation is to establish the provisions on Occupational Safety and Health that must be observed in workplaces, in order to have the conditions to prevent risks and, thus, guarantee workers the right to perform their activities in environments that ensure their life and health, based on the provisions of the Federal Labor Law.

Understanding according to the Official Gazette of the Federation (2017), a Work Center *is any place, whatever its denomination, in which production activities, distribution of goods or provision of services are carried out, or in which people who are subject to an employment relationship work.*

The application and supervision of the Regulation corresponds to the STPS who will be assisted by the labor authorities of the Federal Entities. The STPS will issue the Norms with the purpose of establishing dispositions in the matter of Safety and Health at work that avoid:

Risks that endanger the life, physical integrity or health of the workers; and Adverse and substantial changes in the work environment, which affect or may affect the safety or health of the workers or cause damage to the facilities, machinery, equipment and materials of the Work Center.

ISSN: 2410-3454

In the absence of previous legislation on ergonomics, it is not possible to know specifically the number of injuries caused by dysergonomic causes in the workplace and the penalties imposed on companies for accidents, injuries and occupational diseases in Mexico are not adequately documented because not all companies have their workers insured; However, the Mexican Institute of Social Security, recognizing the importance and transcendence of Ergonomics, created the National Laboratory of Ergonomics and Psychosocial Factors, in the Division of Prevention of Occupational Risks, Industrial Hygiene area, of the Normative Coordination of Occupational Health in the National Medical Center Siglo XXI of the IMSS.

They have a team of professionals in health, engineering, industrial design and psychology, working on various projects for the benefit of Mexican workers, promoting the application of ergonomics in Mexican companies with the requirements and guidelines imposed on the company in this area.

The STPS may issue specific Occupational Safety and Health Standards in the case of those branches or economic activities with particular characteristics that merit a differentiated treatment or that have a higher rate of occupational accidents, disabilities or deaths. Among the relevant aspects of the Regulation is the inclusion of new concepts among which are:

Unsafe Conditions: Those deriving from the non-observance or disregard of the procedures or safety measures set forth in these Regulations and the Standards, and which may lead to the occurrence of incidents, accidents and occupational diseases or material damage to the Work Center.

Occupational Safety and Health Diagnosis: The identification of unsafe or hazardous conditions; of physical, chemical or biological agents or ergonomic or psychosocial risk factors capable of modifying the conditions of the work environment; of the hazards surrounding the Work Center, as well as of the applicable regulatory requirements regarding occupational safety and health.

Favorable Organizational Environment: One that promotes the sense of belonging of workers to the organization; training for the proper performance of the tasks assigned; the precise definition of responsibilities for members of the organization; proactive participation and communication among its members; adequate distribution of workloads, with regular workdays, and the evaluation and recognition of performance.

Compliance Assessment: The determination of the degree of compliance with the Standards.

Psychosocial Risk Factors: Those that can cause anxiety disorders, non-organic sleep-wake cycle disorders and severe stress and adaptation disorders, derived from the nature of the job functions, the type of workday and exposure to severe traumatic events or acts of workplace violence due to the work performed.

Workers with Disabilities: Those who, for congenital or acquired reasons, have one or more physical, mental, intellectual or sensory impairments, whether permanent or temporary in nature.

Workplace violence: Those acts of harassment, bullying or mistreatment against the worker, which may damage their integrity or health.

Ergonomic risk factors: Those that can lead to physical effort, repetitive movements or forced postures in the work performed, with the consequent fatigue, errors, accidents and occupational diseases resulting from the design of facilities, machinery, equipment, tools or workstation.

At this point it should be noted that in Mexico ergonomics is a subject with many gaps in the legislation; in the Federal Regulation of Safety, Hygiene and Working Environment, issued by the Ministry of Labor and Social Welfare and published in the Official Gazette of the Federation on January 21, 1997, it is mentioned:

ISSN: 2410-3454

Ergonomics: Is the adaptation of the workplace, equipment, machinery and tools of the worker, according to his physical and psychological characteristics, in order to prevent accidents and occupational diseases and to optimize his activity with the least effort, as well as to avoid fatigue and human error.

Chapter Ten, Ergonomics, Article 102. The Ministry will promote that in the installations, machinery, equipment or tools of the work center, the employer takes into account ergonomic aspects, in order to prevent accidents and occupational diseases.

Risk: is the probability that damage to the worker's health occurs, such as the adverse effect of a chemical substance, physical, biological and psychosocial factors.

Hazard: General term for anything that has the capacity or potential to cause harm. The hazard associated with a potentially toxic substance depends on: its toxicity and the potential for exposure to it.

Hazards are classified by the ILO as follows:

RISK GROUPS

Group I: Work microenvironment

Group II: Contaminants

Group III: Physical load

Group IV: Psychic load

Group V: Safety

Group I

Microclimate (working environment)

Conditions comfort, found in any environment. Includes: lighting, temperature, humidity, ventilation. (Design, aesthetics, space, color, layout).

Group II: Pollutants

Group III

Workload:

Physical demands: these are the demands imposed on the organism that determine muscular fatigue. Related to: postures, movements, displacements and weight handling.

Group IV

Workload Mental demands

Mental efforts of attention and memory Quantity and quality of information Complexity of response Time pressure Specific individual capabilities. Related to: shifts, rest, breaks, work content, monotony, relationship with people, participation, remuneration, status, identification with the task, initiative, job stability, command style.

Group V

Conditions aimed at eliminating and/or minimizing occupational accidents.

Tools, equipment, appropriate technology, areas and sectorization, electrical energy, cleanliness and order, work clothes, personal protective equipment, first aid kit, health care, training, participation, occupational health committee, accident prevention and follow-up programs, surveillance, disasters, healthy habits.

There are also Official Mexican Standards (NOM), which in some way regulate some aspects in the workplace relevant to ergonomics, issued the functionality and application of the Official Mexican Standard (NOM) NOM-035-STPS, focused on psychosocial factors and NOM-036- STPS oriented to repetitive movements. These standards highlight the concepts of:

Occupational disease, defined as: "...*That caused by physical, chemical or biological agents used or handled during the work activity or present in the workplace...".*

Recognized as such and with a specific relationship to an occupation. There is an evident link between the disease and the work performed.

Mexican Official Standards (NOM).

ISSN: 2410-3454

Regarding the Mexican Official Standards (NOM), for Safety at Work; general provisions are established for Safety that must be observed, among others, in the following matters: The Employer shall:

Review NOM-002-STPS-2010 Use of Machinery, Equipment and Tools.

Review NOM-004-STPS-1999. Prepare a study to analyze the risk to which workers are exposed.

Review NOM-006-STPS-2014 Handling, Transportation and Storage of Materials.

Problem

Companies in general are dynamic places where there is always a rush to fulfill work orders. The study was carried out in an industrial manufacturing plant where a new product was incorporated, with the policy of multifunctional operators; however, due to incapacities and absenteeism they have been insufficient. In addition, the workplace was redesigned and the operators were not trained for the new process. As a result, there have been accidents and even mutilations of upper limb fingers, the conditions can be described as unsafe and the workers' activity also has many unsafe acts, as can be seen in the photographs below.

Based on the above, workers have been incapacitated due to accidents, back, neck, shoulder and upper extremity pain, among other parts of the body, and unjustified absenteeism is frequent, since they only mention that they feel bad about what happened to their coworkers.

Production standards have also been affected by the reduction in the number of workers and the company has not been able to deliver on time and on budget. Likewise, the production standards of those who do attend are diminished due to their slow movements and pain when performing their activities. Due to the great growth of companies worldwide in all types of industries, policies and controls in recent years regarding the prevention of occupational hazards, accidents and occupational diseases worldwide, have taken off because the International Labor Organization (ILO. 2013). (and the World Health Organization (ILO. 2014). show alarming figures of accidents, occupational diseases and deaths in their annual reports.

Preventive culture is the set of ideas, values, attitudes, ways of life, expressed in stable behavior patterns within a society, so that they help to guide, order, promote a desired and expected behavior among its members on how the organization perceives the occupational risk, its consequences and how to deal with it.

It includes the implementation of preventive policies, their execution, evaluation and even modification. (Méndez, E., Figueredo, C., Chirinos, E., Goyo, A. & Rivero, R. 2011).

There are relevant factors that can be a cause of risk such as: the organization and content of work, the length of the working day, remuneration, ergonomics, and psychological pressure. Risks at work are the consequence of the conditions in which work is carried out; work and health deterioration are no longer considered inseparable dimensions. Prevention means acting on the source or origin of the risk, making it possible for work and deterioration of health not to be synonymous.

Working conditions are all the factors involved in the performance of the activity, such as the organization, content and time of work, remuneration, ergonomics, the technology involved, workforce management, social and welfare services, and worker participation.

On the other hand, the work environment indicates the place where the activity is carried out and makes it possible to classify risks according to their nature, and the articulation of these two dimensions configures the overall burden that workers must bear individually and collectively.

The sources susceptible to generate psychological discomfort and physical illnesses in workplaces (depression, back pain, generalized fatigue, among others) are basically of two types: the first is related to the furniture, especially chairs and computer tables; and the second has to do with the environment, such as ventilation and lighting, as well as the square meters available per worker. (Castro, V. 2016).

Accessibility is achieved by thinking about spaces and routes as part of an integral system. An adequate restroom is useless if reaching it involves crossing steps or narrow doorways.

ISSN: 2410-3454

Administrative arrangements are a necessary complement to real estate (Castro, V. 2016).

The following Risk Factors stand out:

- To have an analysis of the Ergonomic Risk Factors of the workstations exposed to them.
- Adopt preventive measures to mitigate Ergonomic Risk Factors in its facilities, machinery, equipment or tools of the Work Center.
- Perform medical examinations to Occupationally Exposed Personnel.
- Inform workers about possible health alterations due to exposure to Ergonomic Risk Factors.
- Train Occupationally Exposed Personnel on safe work practices.
- Keep records on preventive measures taken and medical examinations performed.
- Identify and analyze jobs with psychosocial risk due to the nature of their functions or type of workday.
- Identify workers who were subjected to severe traumatic events or acts of workplace violence, and assess them clinically.
- Adopt relevant preventive measures to mitigate psychosocial risk factors.
- Perform examinations or clinical evaluations of personnel occupationally exposed to psychosocial risk factors.
- Inform workers about possible health alterations due to exposure to psychosocial risk factors.
- Keep records on the preventive measures adopted and the results of examinations or clinical evaluations.

The Regulation states that the STPS (STPS, 2014). will make available to employers various informative programs to facilitate their knowledge and compliance with the regulations on Occupational Safety and Health, including the one related to the identification of the Mexican official standards applicable to the workplace; for the identification and control of personal protective equipment; and the Program for Self-Management in Occupational Safety and Health.

The STPS (2018) makes adjustments to the tabulation imposed in the establishment of sanctions and fines for violations to the precepts of the Regulation. Fines ranging from 50 to 5,000 days of general daily minimum wage in force in the Federal District. $3,505.00 pesos (approximately $194.00 dollars); $350,500.00 pesos (approximately $19,500.00 dollars). It is pertinent to review the General Regulations for Labor Inspection and Application of Sanctions, published in the Official Gazette of the Federation on June 17, 2014.

Given that postures and natural movements are indispensable for an efficient work, it is important that the work station is adapted to the body dimensions of the operator, however, given the great variety of sizes of individuals this is a difficult problem to solve, so it is necessary to create a database with the Anthropometric dimensions and percentiles by regions of the states in Mexico and of each place in the world. For the design of jobs, it is not enough to think of making them for people of average size (50 percentile), it is more appropriate to consider the dimensions of the range zones with percentiles of 95% and 5%, according to the activity to be performed (Chavarría, R. 2005),

Fundamentation

The IOT and OMS state:

Occupational health should focus on: The promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations; to the prevention of damage to health caused by their working conditions; the placement and maintenance of workers in a working environment suited to their physiological and psychological capacities; and, to sum up, the adaptation of work to man, and of each man to his task." (Barba, 2014)

ISSN: 2410-3454

To establish the exposure-effect relationship of a given occupational disease and the correlative activity specific to certain professions, the following are indispensable:

– Clinical and pathological data.

– Analysis of occupational exposure:

– Identify the branch of activity characteristic of the work and of the job (time of exposure, labor seniority) analysis of occupational history.

– Epidemiological data.

– The main focus of occupational health is oriented towards three objectives:

– The maintenance, promotion of workers' health and their ability to work.

– The improvement of the work environment, work conducive to safety and health at work.

– The development of organizations, work cultures in a direction that supports health, safety at work, promote a positive social environment, and increase the productivity of the processes.

The concept of working conditions encompasses the set of factors that influence the physical well-being of workers" They differ from occupational accidents: by the latency period or occurrence of the event.

Productivity as the relationship that exists between the production obtained and the work employed; a situation in which the division of labor, cost reduction, incentives, and rationalization of time and movements intervene, with bilateral benefits to the employer and the worker; and concludes that the great challenge of productivity is the elevation of the competitive capacity of the economy, for the preservation and growth of the productive entity. (SEMAC. 2016).

The physiological aspect, relates the human organism and the workplace, focusing on the reactions of the latter in the physical working conditions, such as fatigue; the economic aspect, highlights the wealth-producing function and the financial benefit it provides to the worker; while the psychological and social dimensions, respectively evidence the interactions between work-personality and work in the context of interpersonal relationships.

Human factors or ergonomics is considered by Niebel, B. & Freivalds, A. (2004). in work design, as a new discipline that addresses the design of tasks, workstations and work environment to better suit the employee. The concept of productivity is multidimensional, influenced by individual characteristics, and involves complex psychosocial processes of human factors to quantify. (Cequea, M., & Núñez M. 2011).

On the other hand, Rincón, L. (2001). points out that some researchers concentrate productivity in the measurement of indicators and the evaluation of their behavior over time; but others recommend devoting more effort to the motivation and participation of workers; considering that if each person acts efficiently, the overall result translates into a productive company.

Regarding the definition, the ILO, in a declaration of the European Agency for Productivity formulated in 1959, in Rome, expressed that: *Productivity is, above all, a mental disposition. It is an attitude that seeks the continuous improvement of what exists. It is the conviction that today we can do more and better than yesterday, and that tomorrow we can do more and better than today. In conclusion, Productivity is a firm belief in the progress of humanity.*

Productivity is the result of three elements: technology, efficiency of technology use, and environmental conditions. Productivity notoriously depends on technology and worker performance, identifying in the latter the ability (knowledge and skills) and motivation (individual need, physical conditions and social conditions) of the worker (Carro, E. & González, C. 2009).

ISSN: 2410-3454

Methodology

According to Martínez, S., Méndez, I., & Murata, C. (2011). the development of methods to evaluate working conditions from the ergonomic point of view, is given based on the specific needs and conditions of the activity being evaluated, makes them focus on the analysis of an area of the task, and although some of the methods involve various aspects within their evaluation, there is no single method that is generally applicable to all activities.

The selection of the assessment method depends on the factors that predominate and represent the greatest risk to the person performing the work, as well as the depth of the analysis required in terms of time and available analysis conditions. In general, the evaluation of working conditions represents great advantages when using work area diagrams, which are simple and quick, allowing the evaluation of the activity at the work site without having to carry it out in a laboratory with simulated and controlled conditions, which may be different from the real situation.

This allows finding and knowing the critical factors that must be corrected to reduce the risk level. However, it is important to consider that the results provided by ergonomic evaluations with these methods only represent a reference or approximation of the level of risk to which the user is exposed and in no case is it an absolute measure.

Achieving an evaluation of potential risks prior to the production process through the participation, training and awareness of the worker should be part of the daily process in the application of current regulations.

The study is developed in an industrial context where the characteristics of the facilities, the environment and the machines were observed, as well as the system that all these elements make up to evaluate the impact on the performance and health of the operators, where problems arise in the specific area of injection, gumming, packaging and packing, from there to take the product to the finished product warehouse.

To carry out this study, Ergonomic methods of evaluation of positions and environmental conditions (lighting, temperature and noise) were used by means of the virtual laboratory of ergonomics, METRIXX VR. In a simplified way, with this technique it is possible to relate in real time the worker's behavior while performing his task with a simultaneous risk level that is long lasting (Wolfgang, L. & Vedder 1983).

The RULA Method is the acronym for Rapid Upper Limb Assessment Method and was developed in 1993 by McAtamney and Corlett, from the University of Nottingham (Institute for Occupational Ergonomics). The risk assessment considers the posture adopted, the duration and frequency of the posture and the forces exerted when the posture is maintained.

For a given posture RULA establishes a certain Performance Level. The Action Level will indicate whether the posture is acceptable or to what extent changes or redesign of the posture are necessary.

The RULA method evaluates individual postures and not sets or sequences of postures, which show the greatest deviation from the neutral position.

For this purpose, the first step consists of observing the body divided into two groups, Group A, which includes the upper limbs (arms, forearms and wrists) and Group B, which includes the legs, trunk and neck. Using the tables associated with the method, a score is assigned to each body zone, and global values are assigned to each of the groups A and B.

The performance levels range from level 1, acceptable, to level 7, urgent need for changes in activity. (Diego-Mas, 2015).

Dysergonomic risks cause a large part of back injuries, abnormal wear of joints and muscles, carpal tunnel syndromes, tendinitis, gastrointestinal and cardiovascular disorders, among others, non-recoverable physical fatigue, increases the harmful effects of other pollutants, since due to fatigue a greater amount of air is inhaled. (Barba, E., Fernández, M., Morales, N. & Rodríguez, A. 2014).

ISSN: 2410-3454

CDF method "Disc Compression Force"., the biomechanical model presented by Chaffin and Anderson (1984), can be used only to determine the L5/S1 disc compression force during a lifting task, but it does not predict the L5/S1 disc compression force.

Lifting task but does not predict the force during a twisting or tilting lift.

The L5/S1 disc (lumbosacral junction) is the point of calculation for disc compression force, because it is the most stressed disc during lifting. The formulas for calculating disc compression are:

$$X1 = 0.1010 * L\ sen\ A1 \quad (1)$$

$$X2 = 0.2337 * L\ sen\ A + 0.0827 * sen\ B\ X_2 \quad (2)$$

$$X3 = 0.2337 * L\ sen\ A + 0.1896 * L * sen\ B + 0.0820 * L\ sen\ C \quad (3)$$

$$X4 = 0.2337 * L\ sen\ A + 0.1896 * L * sen\ B\ 0.1907 * L * sen\ C \quad (4)$$

Then

$$FME = 20(0.363 * M * X1 + 0.062 * M * X2 + 0.050 * M * X3 + W * X4) \quad (5)$$

$$E = (FME*senA)/(FME*cosA + 0.475*M + W)\ \ D = tan\text{-}1E \quad (6)$$

$$FCD = (FME * senA)/senD \quad (7)$$

NIOSH (1994) indicates that compression at L5/S1 exceeding 250 kgs (For Women) and 350 Kgs (For Men) has been shown to impact low back injuries, this compressive force exerted on the low back discs is a function of the length and weight of the upper limbs, the vertical angles of the trunk and upper limbs and the weight of the object lifted.

Sample and Materials

The reason for the study was explained to the workers and they were invited to participate; they conscientiously agreed to participate voluntarily, without coercion or bribery in such a way that neither the human nor personal rights of the workers were affected; nor were the results biased.

As already mentioned, the workers are multifunctional and only two workers were taken because they were the most constant in their activities out of the 18 in the area under study, with the following characteristics

Workstation characteristics were measured because both workers perform the same functions throughout the day as they are multifunctional.

Worker 1(T1)

– Worker's height (1.89 m).

– Weight of worker (90 kg).

– Weight of object being lifted (1.4Kg).

– Male.

– Age 55 years old.

Worker 2 (T2)

– Worker's height (1.48 m).

– Weight of worker (55 kg).

– Weight of object being lifted (72Kg).

– Female.

– Age 20 years old.

The dimensions of the machine (7 x 5 x 2.40 meters), with drive systems, is realized through two extractors that can evacuate about 17,000 m^3 / hour. This results in a pressurized cabin, ready to remove possible contaminants, as shown in Figure 1.

The machining of operational tasks lasts on average 2 hours / day, the rest of the time to complete the eight hours, the operator is responsible for performing the packaging of the parts that have been processed, the transport boxes incorporating the various printed parts and other control tasks.

Figure 1 Mechanization of the Tasks

ISSN: 2410-3454

The operator Operator T1 shows a stretching above the level of man when packing the product in the finished product warehouse, which represents a high risk to the cardiovascular system and in order to identify the level of risk without weight of the Biomechanical Ergonomic Factors, the RULA Method was applied, which is based on movements and twists of the neck, trunk and legs, as shown in Figure 2.

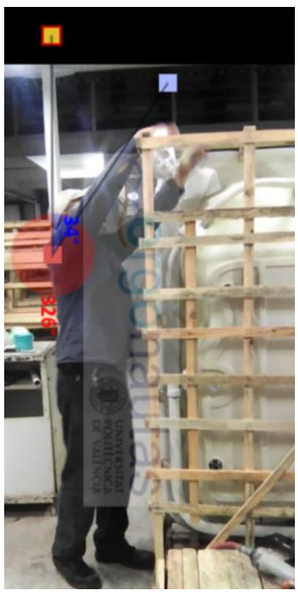

Figure 2 Stretches above the shoulder of the RULA Method

Subsequently, it was applied with the weight of the tool (1.4 k.), as shown in Figure 3.

Figure 3 Stretches above the shoulder of the RULA Method, with weight

Obtaining in both results a score of 7, which represents a high risk and immediate changes.

Worker 2(T2)

For worker number two, the FCD Method was applied, due to the weight and effort he makes in the warehouse area, when pushing the product on the skid and lack of floor maintenance. This static model is very useful when it is intended to evaluate a sporadic lifting during the normal work shift. Once these variables are recorded, we proceed to take a photo in this case of the person we recorded for our project in three different positions (Angle A, B and C) to determine what is the weight that is carrying his fifth vertebra and see if the posture he has is correct when performing these activities.

In order to quantify them objectively, the evaluation was carried out and first the angles were marked, and the formula of the weight exerted on the lever was calculated with Excel software. The Angle of the Arm is Angle B. As shown in Figure 4

Figure 4 Goniometric dimensioning for the CDF Method Angle A

It is also possible to observe its anthropometric characteristics as a risk factor for the activity that it develops and that by not knowing the permissible goniometric and gender limits, it can suffer Cumulative Traumatic Dysfunctions (ATD) or accidents in the short term (Falcon, 2021).

ISSN: 2410-3454

Figure 5 Goniometric dimensioning for the FCD Angle A Method

Figure 6 Goniometric dimensioning for the FCD Angle B Method

Angular values for the forearm, Angle C. Figure 7.

Figure 7 Goniometric dimensioning for the FCD Method, Angle C

Complementary angles for the hip Goniometric tangents, Angle D, are also included:

Figure 8 Goniometric dimensionings hip Angle D in the FCD Method

Figure 9 Goniometric dimensioning for the feet in the FCD Method

Complementary angles for the grip goniometric tangents Angle F:

Figure 10 Goniometric dimensionings for grip in the FCD Method

The result of the evaluation with the FCD method is 325 kilograms in the 5th vertebra, which exceeds the maximum allowable weight of 250 kg. Therefore, it is necessary to rethink the work stations and procedures to avoid accidents and DTAs.

ISSN: 2410-3454

In the evaluation of environmental conditions, direct measurement instruments were used: environmental noise, humidity, heat, and lighting sensors were used with cellular applications. These instruments are placed on the worker or the environment and are responsible for measuring exposure to risk, compared with the permissible conditions in the Mexican Official Standards (NOM's).

Measurements taken in the morning		Measurements taken at noon	
Noise	64dB	Noise	108.9dB
Humidity R.	97.2 HR	Humidity R.	62.76HR
Lighting	107.52 lux	Lighting	158.92lux
Temperature	17.90°C	Temperature	22.50 °C
Vibration	4.3Hz	Vibration	4.4Hz
Heart rate	101.2lps	Heart rate	108.9 lps

Table 1 Environmental Conditions

To verify that the workstations are adequate for the workers, anthropometric measurements were taken as shown in Table 2.

Descr.	Height	Shoulder height	Elbow height	Stretched arm height	Length from vertical to fist	Length from vertical to chest	Shoulder width
T1	189	150	84	217	82	26	43
T2	148	141	106	202	78	25	45
Descr.	Width of clavicles	Floor to mid-shin height	Length from buttock to knee	Shoulder width	Length from hand to middle finger	Hand width	Wrist width
T1	38	38	53	51	19	10	8
T2	32	46	59	45	16	11	6
Descr.	Grip diameter	Foot length	Foot width	Squat height	Height from floor to extended arm	Age	Weight in kg
T1	4	27	11	129	154	49	90
T2	4	26	10	109	145	20	55

Table 2 Anthropometric Measurements of Workers

Conclusions

The development of organizational ergonomics is based on the study of the physical perceptual characteristics of man with the object to be used, information in the design of workstations, controls, visual, auditory or tactile information devices, and includes cognitive processes and its ergonomic methodology is multidisciplinary, since it converges techniques and knowledge from different areas.

Observing the previous results, it is concluded that the operators do not have the adequate conditions for their Goniometric and Anthropometric characteristics; it is also inferred that they do not know their body type and anthropometric measures, implying an overexertion of their capacities.

With respect to the legislation of ergonomics in Mexico, there are still many deficiencies and legal gaps in the Federal Regulation of Safety, Hygiene and Working Environment, issued by the Ministry of Labor and Social Welfare, because there is no specific legislation for ergonomics, it is not possible to know specifically the number of injuries caused by dysergonomic causes in the workplace.

In the research it can be observed that there are no unique ways to evaluate the risk but none has been sufficient, due to the multifactors and the degree of inherent complexity, so it is recommended to expand the studies in this regard, in addition to the fact that although there were only two workers who participated in the study, the results are alarming because of the high risk presented in the working conditions. A broader study and immediate changes in the positions studied are suggested.

Also noteworthy is the lack of knowledge about ergonomics in Mexico. One of the limitations is the lack of trained personnel for its dissemination, which can be seen as an area of opportunity, so complementary studies are recommended in the various lines of research in this discipline, for the generation of knowledge in the national and international context.

References

Barba, E., Fernández, M., Morales, N. & Rodríguez, A. (2014). *Aportes para una cultura de la prevención.* Argentina: OIT

Carro, E. & González, C. (2009). *Productividad científica, conocimiento y uso de fuentes de información en profesores de psicología*. Retrieved November 23, 2016, from:https://cidetac.files.wordpress.com/.../ejemplo-de-extenso-2o-foro-de-investigacic3b3

Castro, V. (2016). *Propuesta de un programa de Salud en el Trabajo, basado en el estudio de riesgos disergonómicos para mejorar la productividad económica*. Chiclayo, Perú: USAT.

Chavarría, R. (2005), *NTP 242: Ergonomía: Análisis Ergonómico de los Espacios de Trabajo en Oficinas*. Retrieved April 13, 2016, from Website:http://www.insht.es/InshtWeb/Contenidos/Documentacion/FichasTecnicas/NTP/Ficheros/201a300/ntp_242.pdf

ISSN: 2410-3454

DOF (2014). *Reglamento Federal de Seguridad y Salud en el trabajo.* Retrieved March 3, 2016 from website: http://www.dof.gob.mx/nota_detalle.php?codigo=5368114&fecha=13/11/2014

DOF (2017). *Reglamento Federal de Seguridad y Salud en el trabajo.* Retrieved November 21, 2021 from website:

Falcón Troncoso, F. J. (2021). Codificación, desarrollo y evaluación de procedimientos de trabajo del sector del mecanizado. https://www.dof.gob.mx/nota_detalle_popup.php?codigo=5507467

Luque, D., Rodriguez, G., & Romero, J. (2006). Accesibilidad y Universidad. Un estudio descriptivo. *Intervención Psicosocial*, 14(2) 209-222.

Martínez, S., Méndez, I., & Murata, C. (2011). Becas, estímulos y sus consecuencias sobre el trabajo y la salud de docentes universitarios. *Reencuentro*, 56-67.

Méndez, E., Figueredo, C., Chirinos, E., Goyo, A. & Rivero, R. (2011). Cultura preventiva del riesgo laboral del docente Universitario. *Multiciencias*, 11(1) 44-49.

Niebel, B. & Freivalds, A. (2004). *Ingeniería Industrial. Métodos, Estándares y Diseño del trabajo*. Colombia. Editorial Alfaomega.

OIT. (2012). Productividad laboral y distribución. *En Enciclopedia de Salud y Seguridad en el Trabajo*, I 291-298) Suiza: OIT.

OIT. (2013). *La prevención de enfermedades profesionales*. Suiza: OIT.

SEMAC. (2016). *La Ergonomía*. Retrieved October 8, 2016, from: http://www.semac.org.mx/index.php/ergonomia.html**.**

STPS (2014). *Normas Oficiales Mexicanas de Seguridad y Salud en el Trabajo.* Retrieved May 3, 2015 from website: http://asinom.stps.gob.mx:8145/Centro/CentroMarcoNormativo.aspx

STPS (2015). *Normas Oficiales Mexicanas de Seguridad y Salud en el Trabajo.* Retrieved July 5, 2017 from website: http://asinom.stps.gob.mx:8145/Centro/CentroMarcoNormativo.aspx

Wolfgang, L. & Vedder (1983). *Ergonomía: Herramientas y Enfoques*. Retrieved September 12, 2016 from: www.insht.es/InshtWeb/Contenidos/Documentacion/TextosOnline/.../tomo1/29.

ISSN: 2410-3454