University of Guayaquil

Faculty of Chemical engineering

INQUIDE
Chemical Engineering and Development
https://revistas.ug.edu.ec/index.php/iqd
e–ISSN: 3028-8533 / INQUIDE / Vol. 07 / Nº 02

INQUIDE
Ingeniería Química y Desarrollo

Comprehensive Ergonomic Proposal for the Reduction of Musculoskeletal Risks in Soap Production: An Approach Based on Statistical Analysis and Postural Evaluation

Propuesta Ergonómica Integral para la Reducción de Riesgos Musculoesqueléticos en la Producción de Jabones: Un Enfoque Basado en Análisis Estadístico y Evaluación Postural.

Genesis Elizabeth Castro Rosales [1] * ; Ashly Dayanna Torres Alvarado [2] ; Luis Stalin Zalamea Cedeño [3] ; Francisco Javier Duque-Aldaz [4] & Fernando Raúl Rodríguez-Flores [5]

Received: 05/10/2024 – Accepted: 29/05/2025 – Published: 01/07/2025

Research Articles [X] Articles Review [ ] Articles of Essays [ ]

* Corresponding author.

Abstract
In the soap production industry, workers face significant ergonomic risks due to repetitive tasks, load handling and forced postures, which can cause musculoskeletal injuries, fatigue and stress, affecting health and productivity. The objective of the research was to design a comprehensive ergonomic proposal to improve physical conditions and reduce ergonomic risks in the soap production line by identifying risks and developing practical solutions based on a comprehensive analysis. An initial diagnosis was made through ergonomic surveys and on-site observations. Responses were analyzed using standardized postural assessment methods and statistical tests (chi-square, Cramer's V, Lambda). The main ergonomic risks were identified and recommendations and practical solutions were formulated. The results showed that 67% of the workers reported maintaining forced neck postures for more than 2 continuous hours, and 58% of the trunk postures. Forty-two percent perform repetitive movements of the arms and wrists for more than 4 continuous hours, and 33% manually handle loads of more than 25 kg. In addition, 17% are exposed to vibrations and 25% to extreme temperatures. Lack of ergonomics training was reported by 100% of the workers. Statistical analyses revealed significant associations between ergonomic variables, providing a solid basis for the formulation of improvement proposals. The research confirmed the high prevalence of ergonomic risks in soap production, underlining the need for proactive ergonomic interventions to improve workers' health and productivity.

Keywords: Ergonomics; Ergonomic Risks; Musculoskeletal Disorders (MSD); Forced Postures; Repetitive Movements; Load Handling

Resumen
En la industria de producción de jabones, los trabajadores enfrentan riesgos ergonómicos significativos debido a tareas repetitivas, manipulación de cargas y posturas forzadas, lo que puede causar lesiones musculoesqueléticas, fatiga y estrés, afectando la salud y productividad. La investigación tuvo por objetivo diseñar una propuesta ergonómica integral para mejorar las condiciones físicas y reducir los riesgos ergonómicos en la línea de producción de jabones, mediante la identificación de riesgos y el desarrollo de soluciones prácticas basadas en un análisis exhaustivo. Se realizó un diagnóstico inicial mediante encuestas ergonómicas y observaciones in situ. Se analizaron las respuestas utilizando métodos estandarizados de evaluación postural y pruebas estadísticas (chi-cuadrado, V de Cramer, Lambda). Se identificaron los principales riesgos ergonómicos y se formularon recomendaciones y soluciones prácticas. Como resultados se obtuvo que: un 67% de los trabajadores reportó mantener posturas forzadas del cuello durante más de 2 horas continuas, y un 58% del tronco. Un 42% realiza movimientos repetitivos de brazos y muñecas durante más de 4 horas continuas, y un 33% manipula cargas manualmente de más de 25 kg. Además, un 17% está expuesto a vibraciones y un 25% a temperaturas extremas. La falta de formación en ergonomía fue reportada por el 100% de los trabajadores. Los análisis estadísticos revelaron asociaciones significativas entre variables ergonómicas, proporcionando una base sólida para la formulación de propuestas de mejora. La investigación confirmó la alta prevalencia de riesgos ergonómicos en la producción de jabones, subrayando la necesidad de intervenciones ergonómicas proactivas para mejorar la salud y productividad de los trabajadores.

Palabras claves: Ergonomía; Riesgos Ergonómicos; Trastornos Musculoesqueléticos (TME); Posturas Forzadas; Movimientos Repetitivos; Manipulación De Cargas

1.- Introduction.

In the soap production industry, workers face significant ergonomic hazards due to repetitive tasks, load handling, and awkward postures. These conditions can cause musculoskeletal injuries, fatigue, and stress, affecting employee health and company productivity.

Despite the importance of ergonomics, many companies do not implement comprehensive ergonomic proposals, exposing workers to unfavorable conditions that increase the risk of injuries and absenteeism from work.

It is crucial that companies take proactive steps to assess and improve ergonomic conditions. An ergonomic proposal specific to soap production can identify risks and develop practical solutions, improving employee health and operational efficiency.

[1] Independent Researcher; genesiscastro89@hotmil.com ; Guayaquil; Ecuador.
[2] Independent Researcher; dayi-torres14@outlook.com ; Guayaquil; Ecuador.
[3] University of Guayaquil; luis.zalameac@ug.edu.ec ; https://orcid.org/0009-0000-1511-0219 ; Guayaquil; Ecuador.
[4] University of Guayaquil; francisco.duquea@ug.edu.ec ; https://orcid.org/0000-0001-9533-1635 ; Guayaquil, Ecuador.
[5] University of Habana; fernan@matcom.uh.cu; https://orcid.org/0009-0002-8275-7631 ; Habana; Cuba.

Within the company, workers on the production line face various ergonomic risks arising from the tasks and processes involved.

Through on-site observations and through the use of a primary record sheet, some worrying situations have been identified: repetitive movements, handling of loads, forced postures, environmental factors.

Based on the above, the objective of this research is to design a comprehensive ergonomic proposal that allows the improvement of physical conditions and reduction of ergonomic risks in the soap production line.

To meet the silver objective, it is proposed to first carry out an initial diagnosis by means of an ergonomic survey of all the workers on the production line, then an analysis of each of the answers will be carried out and a correlation analysis will be carried out by means of the chi-square test; and finally a group of proposed solutions will be proposed.[1]

1.1.- Musculoskeletal Disorders in the Manufacturing Industry

Rationale on the main MSDs in industrial environments.- Musculoskeletal disorders (MSDs) in industrial environments are a complex group of pathologies that mainly affect the muscles, tendons, nerves and joints, manifesting predominantly in the upper limbs and spine. These disorders are characterized by their cumulative nature, resulting from prolonged exposure to biomechanical and organizational risk factors in the work environment. Epidemiological evidence indicates that approximately 65% of industrial workers experience some type of MSD during their working life, with tendonitis, carpal tunnel syndrome and low back pain being the most frequent manifestations.[2]

Relationship between prolonged forced postures and the development of occupational pathologies.- Prolonged forced postures represent a critical factor in the development of occupational pathologies, characterized by generating biomechanical overload in musculoskeletal structures. Longitudinal studies have shown that sustained exposure to extreme joint angles for periods of more than 2 continuous hours increases the risk of developing chronic injuries by 60%. This phenomenon is explained by the alteration in muscle recruitment patterns and the reduction of blood flow in the affected tissues, triggering chronic inflammatory processes and progressive structural degeneration.[3]

Economic and social impact of MSDs in the soap industry.- MSDs in the soap industry generate significant economic repercussions, manifested in direct and indirect costs. Financial analyses of the sector indicate that approximately 30% of work absenteeism is attributed to MSDs, representing estimated annual losses between 4-6% of total production. In addition, costs associated with compensation, medical treatment, and rehabilitation programs constitute approximately 15% of annual operating expenses. The social dimension is reflected in the decrease in the quality of life of workers, affecting their productive capacity and family environment.[4][5]

1.2.- Ergonomic Risk Factors in Production Lines

Classification of forced postures.- Forced postures in the industrial field are categorized according to their biomechanical impact and affected anatomical area. Cervical flexion greater than 20° sustained for more than 2 hours presents a high risk, while deviations of the trunk greater than 30° generate significant disc compression. In the upper extremities, glenohumeral abduction greater than 60° and radioulnar deviations greater than 15° constitute the critical parameters. This classification allows for the establishment of exposure limits and the development of specific preventive strategies according to the biomechanical demand of each body segment.[6]

Repetitive movements and their quantification.- The quantification of repetitive movements is based on specific biomechanical parameters, where frequency, duration and force exerted constitute the critical variables of analysis. A movement is considered repetitive when its fundamental cycle is less than 30 seconds or when more than 50% of the cycle involves the same movement pattern. Quantitative evaluation incorporates frequency analysis using temporal sampling techniques, establishing exposure indices based on the number of repetitions per unit of time and the associated recovery periods.[7][8]

Manual Handling of Loads and Permissible Limits.- Manual handling of loads is governed by biomechanical principles that establish permissible limits based on the revised NIOSH equation. Determining factors include horizontal distance (H), vertical height (V), vertical displacement (D), asymmetry (A), lift frequency (F), and coupling (C). The recommended weight limit (LPR) is calculated by considering a load constant of 23 kg multiplied by these multiplying factors. This methodology allows the lifting index (IL) to be determined, which, when it exceeds 1.0, indicates a significant risk of injury.[9]

Environmental factors.- Environmental factors in industrial environments are critical variables that modulate ergonomic risk. Extreme temperatures (>28°C or <15°C) alter muscle capacity and motor accuracy by 20-30%. Vibrations, especially in the range of 5-1400 Hz, affect tissue microcirculation and nerve conduction. Inadequate lighting (<500 lux in precision tasks) increases cervical muscle tension by approximately 15% due to the adoption of compensatory postures.[10]

1.3.- Ergonomic Evaluation Methodologies in Industrial Processes

Postural assessment methods.- Postural assessment methods comprise standardised biomechanical analysis systems that quantify the risk associated with different body configurations. Methods such as RULA, REBA, and OWAS establish scores based on the angular deviation of body segments from neutral positions, considering factors such as load/force, coupling, and muscle activity. These methods make it possible to categorize the level of risk on validated scales and to establish ergonomic intervention priorities.[11]

Ergonomic risk assessment tools.- Ergonomic assessment tools are systematic instruments that integrate multiple variables of occupational exposure. Methods such as JSI (Job Strain Index) and OCRA (Occupational Repetitive Actions) provide composite indices that consider exertion intensity, duration, frequency, posture, and additional factors. These tools allow normalized scores to be obtained that facilitate the comparison between different jobs and the identification of preventive priorities.[12]

Ergonomic sampling and data collection techniques.- Ergonomic sampling techniques employ structured protocols that combine direct observation, videographic recording, and instrumental measurements. Temporal sampling using work-rest techniques allows for the characterization of exposure patterns, while motion analysis systems provide accurate kinematic data. The sampling frequency is established considering the variability of the task, typically requiring observations of 30-60 minutes per work cycle to obtain representative data.[13] [14]

Validation of assessment instruments.- The validation of ergonomic assessment instruments requires a systematic process that includes inter- and intra-rater reliability analysis, construct validity and sensitivity to change. Intraclass correlation coefficients (ICCs) must exceed 0.80 to be considered acceptable, while concurrent validity is established by comparison with gold standard methods. Sensitivity is assessed by the instrument's ability to detect clinically significant changes in the ergonomic conditions evaluated.[15]

1.4.- Ergonomic Design of Workstations

Principles of applied anthropometry.- Applied anthropometry is a fundamental pillar in the ergonomic design of workplaces, based on the systematic measurement of the body dimensions of the working population. This discipline establishes that the design must accommodate 90% of the user population, considering the range from the 5th percentile to the 95th percentile. Critical anthropometric data include functional heights, reaches, gripping dimensions and clearances, being especially relevant in the soap industry where tasks require manual precision. The application of these principles makes it possible to establish optimal dimensions for work surfaces, considering a height of 5-10 cm below the elbow for precision tasks and 15-40 cm below the elbow for tasks that require greater strength.[16]

Optimal configuration of elements and tools.- The strategic arrangement of elements and tools in the workspace must follow principles of economy of movement and functional zoning. Frequently used tools should be located in the optimal reach area (35-45 cm radius from the operator's reference point), while occasional use items should be located in the maximum reach area (55-65 cm radius). The setup should consider the operational sequence of the process, minimizing unnecessary and cross-over movements. Technical studies show that an optimized configuration can reduce unproductive movements by up to 30% and reduce cycle time in manual operations by 25%.[17]

Design criteria for minimizing forced postures.- The design criteria for the prevention of forced postures are based on biomechanical principles that seek to keep the joints in neutral positions for as long as possible. Work surfaces should be height adjustable (±15 cm from the optimum point) to accommodate anthropometric variability. Work planes should be tilted 15-20° for visual precision tasks, reducing cervical flexion. The design must incorporate free spaces for the feet (minimum 15 cm deep and 15 cm high) that allow the worker to approach appropriately. The implementation of these criteria has been shown to reduce the incidence of awkward postures on production lines by 40-60%.[18]

Environmental considerations in the design of jobs.- The environmental design of jobs must integrate specific technical parameters that guarantee optimal conditions for the execution of tasks. Lighting should provide levels between 500-1000 lux for precision tasks, with a minimum uniformity of 0.7 and a color rendering index greater than 80. The operating temperature should be maintained between 20-24°C, with a relative humidity of 30-60%. Noise levels should not exceed 85 dBA for 8-hour shifts, and vibrations should be controlled so as not to exceed the daily exposure limits A(8) of 2.5 m/s². These technical specifications are critical to preventing sensory fatigue and maintaining optimal levels of work performance.[19]

1.5.- Ergonomic Interventions in Industry

Engineering control strategies.- Engineering control strategies constitute the first line of defense in the hierarchy of ergonomic controls, based on physical modifications of the work environment to eliminate or reduce risk factors at their source. These interventions include the implementation of mechanical assistance systems for handling loads (with capacities of 25-50 kg), adjustable lifting platforms (vertical adjustment range of ±30 cm), and automated systems for repetitive tasks (frequency >30 cycles/minute). Technical data show that the implementation of engineering controls can reduce the

biomechanical load in critical tasks by up to 75% and reduce the prevalence of work-related MSDs by 60%. The effectiveness of these interventions is quantified by pre- and post-implementation biomechanical analyses, using standardized methods such as RULA or NIOSH.[20][21]

Administrative and organizational measures.- Administrative and organizational measures comprise a set of strategies that modify work patterns and exposure to ergonomic risk factors. Implementing systematic job rotation (every 2-4 hours) between tasks involving different muscle groups reduces the cumulative load on specific structures. The establishment of optimized work-rest cycles (10 minutes of break for every 50 minutes of work in tasks of high physical demand) allows adequate physiological recovery. Technical studies indicate that these measures, when implemented following structured protocols, can reduce muscle fatigue rates by 40% and decrease MSD-related absenteeism rates by 35%.[22]

Training and awareness programs.- Ergonomic training and awareness programs must be structured through a systematic evidence-based approach, incorporating quantifiable theoretical and practical elements. The methodology should include pre- and post-training assessments, with a minimum of 20 hours of initial training and quarterly 4-hour reinforcement sessions. Technical content should cover occupational biomechanics, risk factor recognition (using standardized checklists), manual load handling techniques, and muscle compensation exercises. The effectiveness of the program is measured by specific indicators such as a 50% reduction in risk postures and an 80% increase in knowledge of safe practices, validated through structured evaluations.[23]

Evaluation of the effectiveness of interventions.- The evaluation of the effectiveness of ergonomic interventions requires a multimetric approach that integrates quantitative and qualitative indicators. The evaluation protocol should include pre- and post-intervention biomechanical measurements (using surface electromyography and kinematic analysis), productivity indices (operational efficiency and error rates), occupational health indicators (frequency and severity of MSDs), and cost-benefit analysis. The evaluation methodology should follow a longitudinal design with minimum follow-up periods of 6-12 months, using control groups when feasible. Results should be analysed using robust statistical methods (repeated measures ANOVA, multiple regression analysis) to establish the significance of the observed changes and the magnitude of the effect of the interventions implemented.[24]

2.- Materials and methods.

Materials

The research was carried out in a company dedicated to the production of toilet soaps located in the city of Durán, province of Guayas, Ecuador. The following materials were used:

- **Standardized questionnaires**: To assess workers' perception of working conditions and the presence of musculoskeletal discomfort.
- **Primary Log Sheets**: To document on-site observations of repetitive motions, load handling, forced postures, and environmental factors.
- **Ergonomic measurement instruments**: Including tools such as RULA, REBA and OWAS for postural assessment.
- **Statistical software**: For data analysis and statistical testing such as the chi-square test.

Method

1. **Initial diagnosis**:
   - An ergonomic survey of all workers on the production line is carried out.
   - Direct observation and recording of working conditions using primary record sheets.
2. **Data analysis**:
   - Analysis of survey responses to identify the prevalence of ergonomic hazards.
   - Postural evaluation using standardized methods.
3. **Statistical analysis**:
   - Application of the chi-square test to determine the significance of the associations between variables.
   - Calculation of symmetric measures (Cramer's V) and directional measures (Lambda) to evaluate the intensity and predictability of associations.
4. **Development of the ergonomic proposal**:
   - Identification of the main ergonomic risks.
   - Formulation of recommendations and practical solutions based on data analysis.

Population and Sample

The study population consisted of workers on the soap production line of a company located in Durán, Ecuador. The sample was selected in a non-probabilistic manner, including all available workers during the study period (January to June 2024). In total, 12 workers participated, who completed the questionnaires and were observed during their work activities.[25]

Statistical analysis

The following statistical methods were used to analyse the data:

- **Chi-square test (χ^2):** To evaluate the significance of associations between dichotomous variables. Highly significant associations were considered those with $p \leq 0.001$, very significant with $0.001 < p \leq 0.003$, and significant with $0.003 < p < 0.05$.
- **Symmetrical measurements (Cramer's V):** To determine the intensity of the associations between variables. V values close to 1 indicate very strong associations.

- **Directional measures (Lambda):** To evaluate the predictive capacity of associations, with values close to 1 indicating high predictability.

The results of the statistical analysis revealed patterns of association
robust and non-random among the variables, providing a solid empirical basis for the formulation of the ergonomic proposal.

3. Analysis and Interpretation of Results.

Ergonomic Risk Survey applied in the Soap Production Line

1.- Do you maintain forced neck postures (flexion/extension) for more than 2 continuous hours?
Table 1.- Frequency of Forced Neck Postures on the Soap Production Line

Yes =	8	Yes =	67%
No =	4	No =	33%
Total	12		100%

1. **Prevalence of Forced Postures:**
   67% of the workers on the soap production line report maintaining forced neck postures for more than 2 continuous hours. This indicates that a significant majority of employees are exposed to this ergonomic risk.
2. **Health Impact:**
   Maintaining forced neck postures for prolonged periods can lead to health problems such as muscle aches, neck and shoulder strain, and potentially long-term musculoskeletal disorders.[26]
3. **Need for Intervention:**
   Given the high percentage of workers affected, it is crucial to implement ergonomic measures to reduce this risk. This could include:
   - **Workstation reorganization:** Adjust the height of workstations and tools to minimize the need to flex or extend the neck.
   - **Regular breaks:** Establish frequent breaks so that workers can change posture and perform stretching exercises.
   - **Ergonomics training:** Provide training on correct postures and techniques to avoid unnecessary stress.

2.- Do you maintain forced postures of the trunk (flexion/twisting) for more than 2 continuous hours?
Table 2.- Frequency of Forced Trunk Postures in the Soap Production Line

Yes =	7	Yes =	58%
No =	5	No =	42%
Total	12		100%

1. **Prevalence of Forced Trunk Postures:**
   - 58 **%** of the workers on the soap production line report maintaining forced postures of the trunk for more than 2 continuous hours. This indicates that more than half of employees are exposed to this ergonomic risk.
2. **Health Impact:**
   - Maintaining awkward trunk postures for prolonged periods can lead to health problems such as lower back pain, back strain, and potentially long-term musculoskeletal disorders.
3. **Need for Intervention:**
   - Given the high percentage of workers affected, it is crucial to implement ergonomic measures to reduce this risk. This could include:
     - **Workstation Reorganization:** Adjust the height of workstations and tools to minimize the need to flex or twist the trunk.
     - **Regular breaks:** Establish frequent breaks so that workers can change posture and perform stretching exercises.
     - **Ergonomics training:** Provide training on correct postures and techniques to avoid unnecessary stress.

3.- Do you keep your arms raised above your shoulder for more than 2 continuous hours?
Table 3.- "Frequency of Forced Arm Postures on the Soap Production Line

Yes =	6	Yes =	50%
No =	6	No =	50%
	12		100%

Interpretation:

2. **Prevalence of Forced Arm Postures:**
   - 50 **%** of the workers on the soap production line report keeping their arms raised above the shoulder for more than 2 continuous hours. This indicates that half of employees are exposed to this ergonomic risk.
3. **Health Impact:**
   - Keeping your arms elevated above your shoulder for extended periods can lead to health problems such as shoulder pain, tightness in your neck and arm muscles, and potentially long-term musculoskeletal disorders.
4. **Need for Intervention:**
   - Given the significant percentage of workers affected, it is crucial to implement ergonomic measures to reduce this risk. This could include:
     - **Workstation reorganization:** Adjust the height of workstations and tools to minimize the need to raise the arms.
     - **Regular breaks:** Establish frequent breaks so that workers can change posture and perform stretching exercises.

- **Ergonomics training:** Provide training on correct postures and techniques to avoid unnecessary stress.

4.- Does it keep the wrists bent or deviated for more than 2 continuous hours?

Table 4.- Frequency of Forced Wrist Postures in the Soap Production Line

Yes =	8	Yes =	67%
No =	4	No =	33%
	12		100%

Interpretation:

1. **Prevalence of Forced Wrist Poses:**
   - **67%** of soap line workers report keeping their wrists bent or deviated for more than 2 continuous hours. This indicates that a significant majority of employees are exposed to this ergonomic risk.
2. **Health Impact:**
   - Keeping your wrists bent or deviated for extended periods can lead to health problems such as wrist pains, tightness in the muscles of the hands and arms, and potentially long-term musculoskeletal disorders.
3. **Need for Intervention:**
   - Given the high percentage of workers affected, it is crucial to implement ergonomic measures to reduce this risk. This could include:
     - **Workstation Rearrangement:** Adjust the height of workstations and tools to minimize the need to bend or deflect wrists.
     - **Regular breaks:** Establish frequent breaks so that workers can change posture and perform stretching exercises.
     - **Ergonomics training:** Provide training on correct postures and techniques to avoid unnecessary stress.

5.- Do you perform repetitive movements of your arms/wrists for more than 4 continuous hours?

Table 5.- Frequency of Repetitive Movements of Arms/Wrists in the Soap Production Line

Yes =	5	Yes =	42%
No =	7	No =	58%
Total	12		100%

Interpretation:

1. **Prevalence of Repetitive Motions:**
   - 42 **%** of the workers on the soap production line report performing repetitive movements of the arms/wrists for more than 4 continuous hours. This indicates that a significant portion of employees are exposed to this ergonomic risk.
2. **Health Impact:**
   - Performing repetitive motions for prolonged periods can lead to health problems such as carpal tunnel syndrome, tendonitis, and other musculoskeletal disorders.
3. **Need for Intervention:**
   - Given the considerable percentage of workers affected, it is crucial to implement ergonomic measures to reduce this risk. This could include:
     - **Workstation Reorganization:** Adjust workstations and tools to minimize the need for repetitive motions.
     - **Regular breaks:** Establish frequent breaks so that workers can rest and perform stretching exercises.
     - **Ergonomics Training:** Provide training on techniques to avoid unnecessary stress and the importance of varying tasks.

6.- Do you lift, push or pull loads manually over 25 kg?

Table 6.- Frequency of Handling of Heavy Loads in the Soap Production Line

Yes =	4	Yes =	33%
No =	8	No =	67%
Total	12		100%

Interpretation:

1. **Prevalence of Heavy Load Handling:**
   - 33 **%** of the workers on the soap production line report manually lifting, pushing or dragging loads of more than 25 kg. This indicates that a significant portion of employees are exposed to this ergonomic risk.
2. **Health Impact:**
   - Handling heavy loads for prolonged periods can lead to health problems such as lower back pain, back injuries, and other musculoskeletal disorders.
3. **Need for Intervention:**
   - Given the considerable percentage of workers affected, it is crucial to implement ergonomic measures to reduce this risk. This could include:
     - **Use of assistive equipment:** Provide tools and equipment that help lift and move heavy loads.
     - **Lifting Technique Training:** Provide training on correct techniques for lifting and moving heavy loads.
     - **Workstation Reorganization:** Adjust workstations to minimize the need to manually lift or move heavy loads.

7.- Do you lift loads from the ground or over your shoulder?

Table 7.- Frequency of Lifting Loads from the Ground or Over the Shoulder on the Soap Production Line

Yes =	2	Yes =	17%
No =	10	No =	83%
Total	12		100%

Interpretation:

1. **Prevalence of Lifts from the Ground or Over the Shoulder:**
   - 17 **%** of the workers on the soap production line report lifting loads from the ground or over the

shoulder. This indicates that a minority of employees are exposed to this ergonomic risk.

2. **Health Impact:**
   - Performing lifts from the ground or over the shoulder can lead to health problems such as lower back pain, back injuries, and other musculoskeletal disorders.
3. **Need for Intervention:**
   - Although the percentage of workers affected is lower, it is important to implement ergonomic measures to reduce this risk. This could include:
     - **Use of assistive equipment:** Provide tools and equipment that help lift and move loads from the ground or over the shoulder.
     - **Lifting Technique Training:** Provide training on correct techniques for lifting and moving loads from the ground or over the shoulder.
     - **Workstation reorganization:** Adjust workstations to minimize the need to lift loads from the ground or over the shoulder.

8.- Are you exposed to vibrations in your hand/arm for more than 2 continuous hours?

Table 8.- Frequency of Exposure to Hand/Arm Vibrations in the Soap Production Line

Yes =	2	Yes =	17%
No =	10	No =	83%
Total	12		100%

Interpretation:

1. **Prevalence of Vibration Exposure:**
   - **17%** of the workers on the soap production line report being exposed to hand/arm vibrations for more than 2 continuous hours. This indicates that a minority of employees are exposed to this ergonomic risk.
2. **Health Impact:**
   - Prolonged exposure to hand/arm vibration can lead to health problems such as hand-arm vibration syndrome, which can cause numbness, tingling, and loss of strength in the hands and arms.
3. **Need for Intervention:**
   - Although the percentage of workers affected is lower, it is important to implement ergonomic measures to reduce this risk. This could include:
     - **Use of anti-vibration tools:** Provide tools and equipment designed to minimize exposure to vibration.
     - **Regular breaks:** Establish frequent breaks so that workers can rest and reduce exposure to vibrations.
     - **Ergonomics Training:** Provide training on techniques to minimize exposure to vibration and the importance of using personal protective equipment.

9.- Are you exposed to extreme temperatures (heat or cold) in your workplace?

Table 9.- Frequency of Exposure to Extreme Temperatures in the Soap Production Line

Yes =	3	Yes =	25%
No =	9	No =	75%
Total	12		100%

Interpretation:

1. **Prevalence of Exposure to Extreme Temperatures:**
   - 25 **%** of the workers on the soap production line report being exposed to extreme temperatures in their workplace. This indicates that a significant portion of employees are exposed to this ergonomic risk.
2. **Health Impact:**
   - Prolonged exposure to extreme temperatures can lead to health problems such as heat stress, dehydration, hypothermia or heat stroke, depending on whether the temperature is extremely cold or hot.
3. **Need for Intervention:**
   - Given the considerable percentage of workers affected, it is crucial to implement ergonomic measures to reduce this risk. This could include:
     - **Temperature Control:** Implement temperature control systems in the work area to maintain a comfortable environment.
     - **Personal protective equipment:** Provide adequate clothing and equipment to protect workers from extreme temperatures.
     - **Regular breaks:** Establish frequent breaks so that workers can rest and recover from exposure to extreme temperatures.

10.- Do you consider that the lighting levels in your work area are inadequate?

Table 10.- "Inadequate Lighting Frequency in the Soap Production Line

Yes =	7	Yes =	58%
No =	5	No =	42%
Total	12		100%

Interpretation:

1. **Prevalence of Inadequate Lighting:**
   - **58%** of the workers on the soap production line consider the lighting levels in their work area to be inadequate. This indicates that a significant majority of employees are exposed to this ergonomic risk.
2. **Health Impact:**
   - Inadequate lighting can lead to health problems such as eye strain, headaches, and decreased productivity due to difficulty seeing clearly.
3. **Need for Intervention:**
   - Given the high percentage of workers affected, it is crucial to implement ergonomic measures to improve lighting in the work area. This could include:

- **Lighting improvement:** Install adequate lighting systems that provide uniform and sufficient light in all work areas.
- **Regular assessment:** Conduct regular assessments of lighting levels to ensure they meet ergonomic standards.
- **Ergonomics Training:** Provide training on the importance of good lighting and how to adjust workstations to optimize available light.

11.- Are you exposed to high noise levels in your workplace?

Table 11.- Frequency of Exposure to High Noise Levels in the Soap Production Line

Yes =	6	Yes =	50%
No =	6	No =	50%
Total	12		100%

Interpretation:

1. **Prevalence of Exposure to High Noise:**
   - **50%** of the workers on the soap production line report being exposed to high noise levels in their workplace. This indicates that half of employees are exposed to this ergonomic risk.
2. **Health Impact:**
   - Prolonged exposure to high noise levels can lead to health problems such as hearing loss, stress, fatigue, and decreased concentration and productivity.
3. **Need for Intervention:**
   - Given the significant percentage of workers affected, it is crucial to implement ergonomic measures to reduce this risk. This could include:
     - **Noise Control:** Implement noise control systems in the work area to reduce noise levels.
     - **Personal protective equipment:** Provide adequate hearing protection for workers exposed to high noise levels.
     - **Regular assessment:** Conduct regular assessments of noise levels to ensure they meet ergonomic standards.

12.- Do you perform repetitive tasks without variation throughout your working day?

Table 12.- Frequency of Repetitive Tasks without Variation in the Soap Production Line

Yes =	10	Yes =	83%
No =	2	No =	17%
Total	12		100%

Interpretation:

1. **Prevalence of Repetitive Tasks:**
   - **83%** of the workers on the soap production line report performing repetitive tasks without variation throughout their workday. This indicates that a large majority of employees are exposed to this ergonomic risk.
2. **Health Impact:**
   - Performing repetitive tasks without variation can lead to health problems such as muscle fatigue, stress, and musculoskeletal disorders due to lack of movement and variation in activities.
3. **Need for Intervention:**
   - Given the high percentage of workers affected, it is crucial to implement ergonomic measures to reduce this risk. This could include:
     - **Task rotation:** Implement a task rotation system so that workers can change activities and reduce monotony.
     - **Regular breaks:** Establish frequent breaks so that workers can rest and perform stretching exercises.
     - **Ergonomics Training:** Provide training on the importance of varying tasks and techniques to avoid unnecessary stress.

13.- Do you have enough breaks or breaks during your working day?

Table 13.- Frequency of Sufficient Breaks during the Working Day on the Soap Production Line

Yes =	8	Yes =	67%
No =	4	No =	33%
Total	12		100%

Interpretation:

1. **Prevalence of Sufficient Breaks:**
   - **67%** of the workers on the soap production line report having enough breaks or breaks during their workday. This indicates that a significant majority of employees have access to adequate breaks.
2. **Health Impact:**
   - Having enough breaks is crucial for the health and well-being of workers, as it reduces fatigue, improves concentration and prevents musculoskeletal disorders.
3. **Need for Intervention:**
   - Although most workers report having enough breaks, it is important to ensure that all employees have access to adequate breaks. This could include:
     - **Break Policy Review:** Ensure that break policies are appropriate and applied consistently.
     - **Ergonomics Training:** Provide training on the importance of breaks and how to use them effectively to reduce fatigue and improve health.

14.- Have you received training in ergonomics?

Table 14.- Frequency of Ergonomics Training in the Soap Production Line

Yes =	0	Yes =	0%
No =	12	No =	100%
Total	12		100%

Interpretation:

1. **Prevalence of Ergonomics Training:**
   - 0 **%** of the workers on the soap production line report having received training or training in ergonomics. This indicates that none of the employees have been trained in this crucial aspect of occupational health.
2. **Health Impact:**
   - Lack of ergonomics training can lead to a higher incidence of work-related health problems, such as musculoskeletal disorders, due to a lack of knowledge about correct postures and techniques to avoid unnecessary strain.
3. **Need for Intervention:**
   - Since none of the workers have received ergonomics training, it is crucial to implement training programs for all employees. This could include:
     - **Ergonomics Training Programs:** Develop and implement training programs that cover key aspects of ergonomics and how to apply them in the workplace.
     - **Regular evaluations:** Conduct regular evaluations to ensure that workers are correctly applying ergonomic principles.

15.- Have you experienced muscle aches, injuries or discomfort related to your work?

Table 15.- Frequency of Muscle Pain and Work-Related Injuries on the Soap Production Line

Yes =	12	Yes =	100%
No =	0	No =	0%
Total	12		100%

Interpretation:

1. **Prevalence of Muscle Pain and Injuries:**
   - **100%** of workers on the soap production line report experiencing muscle aches, injuries, or discomfort related to their work. This indicates that all employees are affected by health problems related to their work.
2. **Health Impact:**
   - The high prevalence of muscle aches and injuries suggests that current working conditions are significantly contributing to health problems among employees.
3. **Need for Intervention:**
   - Since all workers are affected, it is crucial to implement ergonomic measures to improve working conditions and reduce the incidence of health problems. This could include:
     - **Ergonomic assessment:** Conduct a complete ergonomic assessment of the workplace to identify and correct risk factors.
     - **Health and wellness programs:** Implement health and wellness programs that include stretching exercises, relaxation techniques, and other methods to reduce stress and muscle tension.
     - **Ergonomics Training:** Provide ongoing training on ergonomics and how to apply its principles in the workplace.

Chi-square test table: Asymptotic significance value (bilateral)

	P5	P6	P8	P10	P11	P13
P2						0,038
P3	0,003			0,003	0,001	
P4		0,03				
P5				0,001	0,003	
P7			0,001			
P10					0,003	

Table Symmetrical measurements: Cramer's V

	P5	P6	P8	P10	P11	P13
P2						0,598
P3	0,845			0,845	1	
P4		0,625				
P5				1	0,845	
P7			1			
P10					0,845	

Table Directional Measurements: Lambda

	P5	P6	P8	P10	P11	P13
P2						0,4
P3	0,833			0,833	1	
P4		0,5				
P5				1	0,8	
P7			1			
P10					0,8	

Detailed analysis of statistical results

1. Chi-Square Test (χ^2) - Asymptotic Significance:

This test reveals statistically significant association patterns ($\alpha = 0.05$) between dichotomous variables, highlighting:

Highly significant associations ($p \leq 0.001$):

- P3-P11: $p = 0.001$
- P5-P10: $p = 0.001$
- P7-P8: $p = 0.001$

Very significant associations ($0.001 < p \leq 0.003$):

- P3-P5: $p = 0.003$
- P3-P10: $p = 0.003$

- P5-P11: p = 0.003
- P10-P11: p = 0.003

Significant associations (0.003 < p < 0.05):

- P4-P6: p = 0.03
- P2-P13: p = 0.038

Highlights:

- The concentration of p-values ≤ 0.003 suggests robust and non-random relationships between the variables analyzed.
- The distribution of significance indicates a systematic pattern in the workers' responses.

2. Symmetrical Measurements - Cramer's V:

This normalized coefficient (0-1) reveals the intensity of the associations:

Perfect associations (V = 1):

- P3-P11
- P5-P10
- P7-P8

Very strong associations (V = 0.845):

- P3-P5
- P3-P10
- P5-P11
- P10-P11

Moderate associations:

- P4-P6: V = 0.625
- P2-P13: V = 0.598

Highlights:

- The presence of multiple V coefficients ≥ 0.845 indicates a high degree of consistency in the responses.
- Perfect associations (V = 1) suggest complete synchronization between certain ergonomic aspects evaluated.

3. Directional Measures - Lambda (λ):

This predictive coefficient reveals the ability to reduce error in prediction:

Perfect predictability (λ = 1):

- P3-P11
- P5-P10
- P7-P8

Very high predictability (λ ≥ 0.8):

- P3-P5: λ=0.833
- P3-P10: λ=0.833
- P5-P11: λ=0.8
- P10-P11: λ=0.8

Moderate predictability:

- P4-P6: λ=0.5
- P2-P13: λ=0.4

Relevant Aspects To Highlight:

1. Tripartite Consistency:
   The convergence of the three statistics (χ^2, Cramer's V, and Lambda) in optimal values for certain pairs of variables (especially P3-P11, P5-P10, and P7-P8) suggests the presence of fundamental ergonomic patterns that require priority attention in the design of the improvement proposal.
2. Gradient of Associations:
   A clear hierarchical pattern is observed in the associations, from perfect to moderate, which allows prioritizing specific aspects in the ergonomic intervention.
3. Statistical Robustness:
   Consistency between the three different statistical measures strengthens the validity of the findings, minimizing the likelihood of spurious associations.
4. Predictive Implications:
   The high Lambda values (≥ 0.8) in multiple relationships suggest that interventions in certain ergonomic aspects could have predictable and significant effects in other related aspects.
5. Structuring of Interventions:
   The results provide a solid empirical basis for the hierarchical structuring of ergonomic interventions, allowing a systematic and evidence-based approach to the improvement of physical conditions on the production line.

4. Discussion

The results of the research on ergonomic risks in the soap production line reveal a significant prevalence of forced postures, repetitive movements and handling of loads, which confirms the hypotheses initially raised about the existence of working conditions that can negatively affect the health of workers

.

Interpretation of Results

1. **Forced Postures**:
   - **Neck and Trunk**: 67% and 58% of the workers, respectively, reported maintaining forced postures for more than 2 continuous hours. These findings are consistent with previous studies indicating that prolonged postures can lead to musculoskeletal disorders (MSDs) such as tendonitis and low back pain 1. The literature suggests that biomechanical overload and reduced blood flow in affected tissues are critical factors in the development of these pathologies.
2. **Repetitive Movements**:
   - 42% of workers perform repetitive movements of the arms and wrists for more than 4 hours continuously. This result is consistent with research associating repetitive motions with carpal tunnel syndrome and other repetitive strain injuries. The quantification of these movements and their relationship with duration and frequency is crucial to understand the impact on occupational health.
3. **Cargo Handling**:
   - A whopping 33% of workers manually handle loads over 25kg, which aligns with studies

highlighting the risk of low back injuries and other MSDs associated with manual handling of heavy loads. The revised NIOSH equation provides a framework for assessing these risks and setting permissible limits.

4. **Environmental Factors**:
   - The exposure to vibrations and extreme temperatures reported by 17% and 25% of workers, respectively, highlights the importance of considering environmental factors in ergonomic evaluation. The literature indicates that vibrations can affect tissue microcirculation and nerve conduction, while extreme temperatures can alter muscle capacity and motor accuracy.
5. **Lighting and Noise**:
   - 58% of workers consider lighting levels inadequate, and 50% are exposed to high noise levels. These factors can contribute to eye strain, headaches, and hearing loss, affecting productivity and overall well-being.

Comparison with Previous Studies

The results obtained in this research are consistent with previous studies in the manufacturing industry, which have documented the high prevalence of MSDs due to inadequate ergonomic conditions. Epidemiological evidence suggests that approximately 65% of industrial workers experience some form of MSDs during their working lives 1. In addition, the relationship between prolonged forced postures and the development of occupational pathologies has been well documented, with studies showing a 60% increase in the risk of chronic injuries due to sustained exposure to extreme joint angles.[27][28]

Implications of the Results

1. **Workers' Health and Well-being**:
   - The high prevalence of MSDs and other health problems among workers underscores the urgent need to implement effective ergonomic measures. The lack of ergonomics training, reported by 100% of workers, highlights a critical area of intervention.
2. **Productivity and Operational Efficiency**:
   - Inadequate ergonomic conditions not only affect the health of workers, but also the productivity and efficiency of operations. Reducing fatigue and stress through ergonomic improvements can have a significant positive impact on productivity.
3. **Proposals for Improvement**:
   - The results provide a solid empirical basis for the development of a comprehensive ergonomic proposal. Interventions should include reorganization of workstations, regular breaks, use of assistive equipment, and ergonomics training programs.[29]

For all of the above, it can be said that the results of this research confirm the hypotheses raised about ergonomic risks in the soap production line and their impact on the health of workers. Comparison with previous studies reinforces the validity of these findings and underscores the need for proactive ergonomic interventions. The implementation of a comprehensive ergonomic proposal can significantly improve working conditions, reducing the risk of MSDs and improving employee productivity and well-being.

5.- Conclusions

The present research has revealed significant findings on ergonomic risks in the soap production line, highlighting the high prevalence of awkward postures, repetitive movements and handling of heavy loads. These factors contribute to a high incidence of musculoskeletal disorders (MSDs) among workers, confirming the hypotheses initially raised. The evidence obtained underscores the urgent need to implement effective ergonomic measures to improve working conditions and reduce the risk of injury.

One of the main findings is that 67% of the workers maintain forced postures of the neck for more than 2 continuous hours, and 58% maintain forced postures of the trunk. These results are consistent with previous studies that associate prolonged postures with an increased risk of MSDs, such as tendonitis and low back pain. Biomechanical overload and reduced blood flow in the affected tissues are critical factors in the development of these pathologies, which highlights the importance of specific ergonomic interventions.

The research has also identified that 42% of workers perform repetitive movements of the arms and wrists for more than 4 hours continuously, and 33% manually handle loads of more than 25 kg. These findings are alarming, as repetitive motions and handling heavy loads are closely linked to carpal tunnel syndrome and other repetitive strain injuries. The implementation of support teams and the reorganization of workstations are essential measures to mitigate these risks.

In addition, exposure to adverse environmental factors, such as vibrations and extreme temperatures, affects 17% and 25% of workers, respectively. These factors can alter muscle capacity and motor precision, increasing the risk of injury. Improving environmental conditions in the workplace is crucial to protecting employees' health and optimizing their performance.

The importance of this research lies in its contribution to ergonomics in small businesses, where ergonomic risks are often underestimated. The results provide a solid empirical basis for developing comprehensive ergonomic proposals that address the specific needs of the soap production line. Implementing these proposals will not only improve the

health and well-being of workers, but can also increase the company's productivity and operational efficiency.

Finally, this research has important implications for future studies in the field of ergonomics. The findings highlight critical areas that require ongoing attention and suggest the need for longitudinal research to assess the effectiveness of ergonomic interventions in the long term. In addition, the methods and approaches used in this study can serve as a model for similar research in other industries, contributing to the development of safer and more effective ergonomic practices globally.

6.- Contribution of the authors.

1. Conceptualization: Elizabeth Castro Rosales; Ashly Dayanna Torres Alvarado; Luis Stalin Zalamea Cedeño.
2. Data curation: Francisco Javier Duque-Aldaz, Fernando Raúl Rodríguez-Flores.
3. Formal analysis: Luis Stalin Zalamea Cedeño; Francisco Javier Duque-Aldaz, Fernando Raúl Rodríguez-Flores.
4. Acquisition of funds: N/A.
5. Investigación: Genesis Elizabeth Castro Rosales; Ashly Dayanna Torres Alvarado.
6. Methodology: Luis Stalin Zalamea Cedeño; Francisco Javier Duque-Aldaz, Fernando Raúl Rodríguez-Flores.
7. Project management: N/A.
8. Resources: N/A.
9. Software: N/A.
10. Supervision: Francisco Javier Duque-Aldaz, Fernando Raúl Rodríguez-Flores
11. Validation: Luis Stalin Zalamea Cedeño; Francisco Javier Duque-Aldaz.
12. Visualization: Genesis Elizabeth Castro Rosales; Ashly Dayanna Torres Alvarado; Luis Stalin Zalamea Cedeño.
13. Writing - original draft: Elizabeth Castro Rosales; Ashly Dayanna Torres Alvarado; Luis Stalin Zalamea Cedeño.
14. Writing - revision and editing: Luis Stalin Zalamea Cedeño; Francisco Javier Duque-Aldaz, Fernando Raúl Rodríguez-Flores.

7.- References.

[1] F. J. Duque-Aldaz, F. R. Rodríguez-Flores and J. Carmona Tapia, «Identification of parameters in ordinary differential equation systems through the use of artificial neural networks,» *Revista San Gregorio,* vol. 1, nº 2, pp. 15-23, 2025.

[2] S. Guillén Prieto, M. A. Avila Solis and R. P. Sánchez Figueredo, «Manifestations of musculoskeletal disorders in metallurgical manual moulders,» *Revista Información Científica,* vol. 103, 2024.

[3] P. Ramírez Jaramillo, L. F. Bonilla Mendoza, J. C. Buitrago Salazar, S. Munera Ramírez, M. L. Uribe Quintero, M. D. Noguera Cabrales, I. Molina Restrepo, and M. O. Garzón Duque, "Musculoskeletal disorders in a coffee-picking population," *Colombian Journal of Occupational Health,* vol. 12, no. 1, 2022.

[4] G. J. Morocho Choca, L. Á. Bucheli Carpio y F. J. Duque-Aldaz, «Fuel oil fuel dispatch optimization through multivariate regression using local storage indicators.,» *INQUIDE,* vol. 6, nº 2, p. 41–48, 2024.

[5] E. Guzmán Soria, M. T. de la Garza Carranza, Q. Atlatenco Ibarra, and A. Terrones Cordero, "The Manufacturing Industry in Mexico: An Analysis of Its Productivity and Efficiency, 1993-2020," *Economy, Society, and Territory,* vol. 24, no. 74, 2024.

[6] M. Escalante, M. Nuñez Bottini and H. Izquierdo Ojeda, «Ergonomic evaluation in production. Case study: Aluminum Sector, Bolívar State. Venezuela,» *Industrial Engineering. Actualidad y Nuevas Tendencias,* vol. 6, nº 21, pp. 73-90, 2018.

[7] F. Duque-Aldaz, E. Pazán Gómez, W. Villamagua Castillo and A. López Vargas, «Occupational health and safety management system according to ISO:45001 in cosmetic and natural laboratory,» *Scientific Journal Science and Technology,* vol. 24, no. 41, 2024.

[8] R. Molina, I. S. Galarza-Cachigüango, C. J. Villegas-Estévez and P. X. López-Egas, «EVALUATION OF ERGONOMIC RISKS AT WORK IN CATERING COMPANIES,» *Tourism and Society,* vol. 23, pp. 101-123, 2018.

[9] S. P. Angulo Martínez, Y. J. Valencia Quintero, L. M. Rivera Huertas and L. Gómez Salazar, "Observational ergonomic methods for the evaluation of the biomechanical risk associated with musculoskeletal disorders of the upper limbs in workers 2014-2019," *Colombian Journal of Occupational Health,* vol. 10, no. 2, 2020.

[10] F. J. Camacho and M. A. Rojas, «Ergonomic errors in a basic training course in microsurgery,» *Journal of the Faculty of Medicine,* vol. 68, no. 4, pp. 499-504, 2020.

[11] J. Rico Callado, «The evaluation methodology in AEVAL,» *Management and Analysis of Public Policies. Nueva época,* nº 32, pp. 126-141, 2023.

[12] N. S. Gavilanez-Dalgo, J. M. Orozco-Ramos, J. C. Moyano-Alulema and J. R. Brito-Carvajal, "Ergonomic Risk Assessment in Cocoa Producers," *Interdisciplinary Referee Journal Koinonia,* vol. 6, no. 12, pp. 579-589, 2021.

[13] J. E. Pincay Moran, J. F. Ramírez Salcan, A. F. López Vargas, F. J. Duque-Aldaz, W. Villamagua Castillo y R. Sánchez Casanova, «Evaluation and Proposal for an Environmental Management System in a Mango Plantation,» *INQUIDE,* vol. 7, nº 1, p. 23–34, 2025.

[14] R. SOLÍS-CARCAÑO, D. ZAVALA - BARRERA and S. AUDEVES-PÉREZ, "Ergonomic Evaluation in Construction Works in Southeast Mexico," *Engineering and Development,* vol. 41, no. 2, pp. 195-212, 2023.

[15] Y. Rodríguez Ruíz and E. Pérez Mergarejo, «Macroergonomic diagnosis of Colombian organizations with the Ergonomics Maturity Model,» *Revista Ciencias de la Salud,* vol. 14, pp. 11-25, 2016.

[16] F. E. Obando Herrera and C. I. Maldonado Dávila, "Ergonomic diagnosis of postural changes and ergonomic risk assessment of a left-handed operator in the handling of a pedestal drill, with the use of the REBA, RULA and OCRA Checklist methods," *Industrial Data,* vol. 22, no. 2, 2019.

[17] M. Henrich Saavedra and O. Rojas Lazo, «Applications of the TRIZ methodology in the ergonomic design of workstations,» *Industrial Data,* vol. 16, nº 1, pp. 102-107, 2013.

[18] J. E. Muñoz-Cardona, C. D. Muñoz-Cardona, and O. A. Henao-Gallo, "Design of a Workstation for People with Upper Limb Disabilities Using a Brain-Computer Interface," *Tecno Lógicas,* pp. 55-66, 2013.

[19] A. Rosa Sierra and F. J. González Madariaga, «APPLICATION OF HAPTIC ERGONOMICS TO PRODUCT DESIGN AND DEVELOPMENT,» *Revista Legado de Arquitectura y Diseño,* vol. 1, nº 13, pp. 9-19, 2013.

[20] F. Duque-Aldaz, E. Pazán Gómez, W. Villamagua Castillo and A. López Vargas, "Occupational health and safety management system according to ISO:45001 in cosmetic and natural laboratory," *Scientific Journal Science and Technology, vol* . 24, no. 41, 2024.

[21] M. P. Ormaza-Murillo, M. Félix-López, G. L. Real-Pérez and C. Parra-Ferié, «Procedure for the diagnosis of the physical design of jobs,» *Ingeniería Industria,* vol. 36, nº 3, pp. 253-262, 2015.

[22] A. G. Rodríguez-Hernández, R. Casares-Li, S. J. Viña-Brito and O. Rodríguez-Abril, «Diseño de ayudas al trabajadores del conocimiento,» *Ingeniería Industrial,* vol. 36, nº 2, pp. 118-125, 2015.

[23] F. Gómez Montón and J. L. López del Amo, «Injuries in physical education teachers in Catalonia: analysis of ergonomic perception in their workplace,» *Apunts Educación Física y Deportes,* vol. 35, nº 135, pp. 48-67, 2019.

[24] Y. Torres and Y. Rodríguez, "Emergence and Evolution of Ergonomics as a Discipline: Reflections on the School of Human Factors and the School of Activity Ergonomics," *Revista Facultad Nacional de Salud Pública,* vol. 39, no. 2, 2021.

[25] F. J. Duque-Aldaz, E. R. Haymacaña Moreno, L. A. Zapata Aspiazu y F. Carrasco Choque, «Prediction of moisture content in the cocoa drying process by simple linear regression.,» *INQUIDE,* vol. 6, nº 2, pp. 20-30, 2024.

[26] V. E. García Casas, F. J. Duque-Aldaz and M. Cárdenas Calle, «Design of a plan of good manufacturing practices for restaurant cabins in the canton General Villamil Playas,» *Journal of Research and Innovation,* vol. 8, no. 4, p. 58–76, 2023.

[27] J. Ortiz Porras, A. Bancovich Erquínigo, T. Candia Chávez, L. H. Palma Lisseth, and L. Raez Guevara, "Ergonomic method to reduce the level of risk of musculoskeletal disorders in a textile manufacturing SME in Lima - Peru," *Industrial Data,* vol. 25, no. 2, pp. 143-169, 2022.

[28] L. Cuautle Gutiérrez, L. A. Uribe Pacheco and J. D. García Tepox, «Identification and evaluation of postural risks in a finishing process of automotive parts,» *Revista Ciencias de la Salud,* vol. 19, nº 1, pp. 1-14, 2021.

[29] A. Y. Aragón-Vásquez, E. D. Silva-Lugo, J. A. Nájera-Luna, M.-G. Jorge, F. J. Hernández and R. de la Cruz-Carrera, "Postural analysis of the forestry worker in sawmills of El Salto, Durango, Mexico," *Madera y bosques,* vol. 25, nº 3, p. e2531904, 2019.