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Ergonomic evaluation of medical staff in Laparoscopic and General Surgery at “Hospital Teófilo Dávila” in Machala.

Trabajo de integración curricular presentado como requisito para la obtención del título de Ingeniera Biomédica

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DEDICATORIA

A mis padres Rommel y Miroslava, y hermano Rommelito, por apoyarme en cada decisión y proyecto que tomé, por su amor infinito, y por luchar a mi lado para alcanzar cada meta y sueño planteado. Son los pilares de mi vida.

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RESUMEN

El presente estudio fue realizado en los quirófanos del Hospital Teófilo Dávila, ubicado en la ciudad de Machala. En este centro hospitalario, se realizó un estudio ergonómico con tres diferentes métodos: RULA, REBA y OCRA y un cuestionario nórdico modificado, durante el mes de enero y febrero del 2021, con la intervención quirúrgica de 8 médicos cirujanos de 5 diferentes especialidades.

El objetivo principal de esta investigación fue determinar y analizar el riesgo ergonómico de los cirujanos durante las intervenciones quirúrgicas para obtener una relación entre las posturas inadecuadas adoptadas por los médicos y los trastornos musculoesqueléticos. Así, se obtendrá el riesgo ergonómico al que se encuentran expuestos para ayudar a prevenir o disminuir sus dolencias.

El cuestionario nórdico nos ayudó con la información personal y las principales variables como edad, género y horas de trabajo, además, nos dio una idea general de las dolencias que padecían los médicos actualmente y a que factores de riesgo estaban expuestos. El método RULA mostró que el 85% de las posturas de los cirujanos están en el nivel de riesgo 4, el nivel de riesgo más altos y que requiere cambios inmediatos, y el 15% de las posturas están en el nivel de riesgo 3, el cual requiere rediseño de la tarea. El método REBA mostró que el 10% de las posturas están en el nivel 4, de riesgo muy alto, siendo necesario la actuación de inmediato. El 50% de las posturas están en el nivel 3, de riesgo alto por lo que es necesario la actuación en cuanto antes y el 40% de las posturas están en el nivel 2, de riesgo medio por lo que es necesario la actuación. El método OCRA Check List mostró que el 20% de las posturas están en un nivel de riesgo Aceptable que no requiere acción; el 45% están en el nivel Inaceptable Medio y el 35% en el nivel Inaceptable Alto, por lo que se recomienda mejora del puesto, supervisión médica y entrenamiento para ambos niveles. Finalmente, mediante un análisis con chi cuadrado se pudo demostrar la directa relación de las posturas inadecuadas con los trastornos musculoesqueléticos en el personal médico.

Las lesiones osteomusculares, especialmente en la espalda y en el cuello están presentes en la mayoría de los médicos, mismas que requieren una actuación inmediata. Las lesiones en muñecas, codos y hombros son menores, sin embargo, deben estar bajo una supervisión médica.

Palabras clave: Ergonomía, RULA, REBA, OCRA, Cirujanos, Cirugía General, Cirugía Laparoscópica.

ABSTRACT

The present study was realized in the operating rooms of "Hospital Teófilo Dávila" located in Machala city. An ergonomic evaluation was carried out with three different methods: RULA, REBA and OCRA and a Nordic modified questionnaire, during the months of January and February of 2021, with the surgery intervention of 8 surgeons from 5 different specialties.

The main objective of this research was to determine and analyze the ergonomic risk of surgeons during surgical interventions in order to obtain a relationship between the inadequate postures adopted by physicians and musculoskeletal disorders. Thus, the ergonomic risk to which they are exposed will be obtained to help prevent or reduce their ailments.

The Nordic questionnaire helped us with personal information and the main variables such as age, gender, and working hours, and also gave us a general idea of what ailments the physicians were currently suffering from and what risk factors they were exposed to. RULA method showed that 85% of surgeons' postures are in level 4 and 15% are in level 3, so the investigation and changes are required immediately. REBA method showed that 10% of surgeons' postures are in level 4. 50% are in level 3 of very high and high risk, respectively, which a necessary soon action is required. The remaining 40% are in level 2 of medium risk that requires a necessary action. OCRA Check List method showed that 20% of surgeons' postures are in Acceptable risk level which not required action. The 45% are in medium risk level and 35% are in high-risk level, so recommended job upgrading, medical supervision and training is required. Finally, a chi-square analysis was used to demonstrate the direct relationship between inadequate posture and musculoskeletal disorders in medical personnel.

Musculoskeletal injuries, especially in the back and neck, are present in most surgeons and there are the ones that require immediate action. Injuries to the wrists, elbows and shoulders are minor but should be under medical supervision.

Keywords: Ergonomics, RULA, REBA, OCRA, Surgeons, General Surgery, Laparoscopic Surgery.

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List of Abbreviations

- MSDs – Musculoskeletal Disorders
- RULA – Rapid Upper Limb Assessment
- REBA – Rapid Entire Body Assessment
- OCRA – Occupational Repetitive Action
- ILO – International Labour Organization
- IEA – International Ergonomic Association
- OWAS
- ISO – International Organization for Standardization
- GNP – Gross National Product
- TNTR – Net Duration of Repetitive Work
- TNC – Net Totalcycle Time
- ICKL – OCRA Checklist Index
- FR – Recovery Time Factor
- FF – Frequency Factor
- ATD – Dynamic Technical Actions
- ATE – Static Technical Actions
- FFz – Force Factor
- FP – Posture Factor
- PHo – Posture of Shoulders
- PCo – Posture of Elbow
- PMu – Posture of Wrist
- PMa – Posture of Hand
- Pes – Sterotypy Movements
- FC – Additional Factors
- Fso – Socio-organizational Factors
- Ffm – Physico-mechanical Factors
- MD – Duration Multiplier

CHAPTER 1

1.1. INTRODUCTION

Ergonomics is the study of the interaction between the human body and the environment. In this sense, the term environment is taken to cover not only the ambient environment in which he may work but also his tools and materials, his methods of work, and the organization of his work, either as an individual or within a working group(Murrell, 1965). Ergonomics analyzes the biomechanics of the body and the interactions between human-equipment, human-computer, human-system, human-environment and human-human interaction (Wilson, 2000). This discipline uses different methods according to the analyzed worker, type of work, and other factors such as place of work, tools, gender, or age, to design an adequate work environment.

The ergonomics systems improve the work effectiveness, the health of people studied and provides an ergonomic plan to suit each worker in the study case. However, this practice is limited in Ecuador because is commonly used only in industry or heavy-load work, leaving aside jobs that do not require extrema loads or effort such as people working in offices or medical staff. Current, ergonomic methods are almost nonexistent in Ecuador health institutions, so the ergonomic measures are just regulating the surgical table and short breaks (Iturralde, 2014).

Musculoskeletal injuries are accumulative traumatisms that affect the muscles, tendons, nerves, and blood vessels. This problem is developed by extreme forces, inadequate postures, or physical stress. The effects of these problems are reflet in a decrease in productivity, debility in movements, or fatigue in job (Iturralde, 2014).

The present work is focused on implement ergonomic methods according to the postures and works those surgeons realize, so the three methods selected are RULA, REBA and OCRA. These tools evaluated the postural load, awkward postures, and repetitive movements, respectively, in order to determine the ergonomic risk to which surgeons are exposed at “Hospital Teófilo Dávila” in Machala, during the surgeries of respective specialties. In addition, it provides guidance to prevent musculoskeletal injuries.

1.2. GENERAL AND SPECIFIC OBJECTIVES

General objective:

Determine and analyze the ergonomic risk of surgeons, from different specialties with 3 ergonomic methods, REBA, RULA and OCRA; during general and laparoscopic surgeries at "Hospital Teófilo Dávila" in Machala.

Specific objectives:

- To evaluate the positions adopted by surgeons during surgical interventions with REBA, RULA and OCRA systems.
- To correlate the musculoskeletal disorders with the inadequate postures of surgeons.
- To propose new conditions for the operating rooms, according to the ergonomic principles.

1.3. PROBLEM STATEMENT

The inadequate postures demand a greater effort and can cause musculoskeletal injuries, due to muscular tension and nerve compressions. These problems increase if the extreme postures are accompanied by a working environment designed in a way that is unnatural for the human body and the tools used do not meet functionality and ergonomics requirements (Iturralde, 2014).

The operating room work requires a great deal of precision and attention, so the surgeons are exposed to work under high stress with extreme posture according to the type of surgery and patient, repetitive movements, and mental fatigue. Then, the surgery may last longer than expected and the surgeons suffer from dorsal-lumbar pains.

An ergonomic evaluation indicates the risk factors to prevent futures injuries and allows us to identify if a job position is optimal. However, in Ecuador, the use of ergonomics in the health sector is scarce and in the operating room is practically non-existent (Hidalgo, 2015). Therefore, this study aims to benefit surgeons to make them aware of their posture and musculoskeletal problems. In addition, other advantages are improving the surgery results, benefits for the patients and the modification of the operating room according to the surgeon's postures (Alaqeel & Tanzer, 2020).

To achieve this goal, the implementation of new techniques, such as ergonomics methods is crucial to obtain good postures and a safe workplace environment, in order to improve occupational health. The good practices of ergonomics systems help in the health of surgeons and increase the quality of the surgical interventions.

In this context, this project proposes the application of three ergonomic systems, REBA, RULA and OCRA methods to study and analyze the ergonomic risks of surgeons in interventions of different specialties and give a recommendation that decreases musculoskeletal injuries. These ergonomic systems were chosen according to type and location of damage, type of work, work environment, body movements, and loads and forces involved.

CHAPTER 2

2.1. STATE OF THE ART

2.1.1. History of Ergonomics

The history of ergonomics began in ancient Greece from medieval medical accounts of interactions between people and their workers' environment. In the UK, from 1939 to 1945 in World War, emerges the modern ergonomics where appears people interested in the effectiveness of human performance in anatomy, physiology, psychology, industrial medicine, industrial hygiene, design engineering, architecture, and illumination engineering (Wilson, 2000). In the same way, in United States, Germany, Netherland, and other European countries, ergonomics was important due to the increment in industrial engineering.

The current ergonomics systems are the results of the convergence of several scientific disciplines and technologies in order to improve the life of people. From anatomy and physiology, we learn about the structure and functioning of the human body. Anthropometry gives information on body size. Physiological psychology deals with the functioning of the brain and of the nervous system. Experimental psychology seeks to define the parameters of human behavior. Industrial medicine can help to define those conditions of work which may prove harmful to the human structure. From physics and to some extent engineering will come knowledge of the conditions with which the worker has to contend (Murrell, 1965). In principle, ergonomics encompassed the social, psychological, cultural, and organizational environments of systems, however, to date it has been viewed as concerned with the individual components of the physical environment (Parsons, 2000).

2.1.2. Types of Ergonomics

The International Ergonomics Association (IEA) define the employers and the elements of work how a one system. Theory, dates, principles, and methods are applied to improve the performance of the system. Therefore, IEA classified ergonomics as follows (Gomes, 2014).

Table 1 Types of Ergonomics and its Characteristics

Types of Ergonomics	Characteristics
Physical	Study the human anatomy and biomechanical characteristics such as repetitive movements, extreme posture or occupational health and safety.
Cognitive	Is related with the mental processes, motor response and reasoning to study the interaction between human and the elements of the system, such as human-computer interaction or decision making
Organizational	Include political structures and processes of the organization. The topics to be covered are working hours, community ergonomics, quality management and communication

2.1.3. Ergonomics Risk Factors

The risk factors can be material or immaterial such as are objects, workplace, equipment, or tools whose weight, size, shape or design cause overstress, awkward postures or inadequate movements result in musculoskeletal disorders and physical fatigue.

According to Iturralde (Iturralde, 2014) indicate that the relevant risk factors, which workers are most exposed, are forced postures and repetitive movements, followed by the manipulation of loads and the exertion of significant forces. However, there is a wide variety of physical, psychosocial, and organizational factors inherent in a job. Some of them are the duration of physical activity, vibrations, rate of movement and vibration, recovery, statics muscle work, age, experience, work environment, teamwork, among others (David, 2005). These exposure factors are defined depending on the type of work and the selected ergonomic method.

2.1.4. Ergonomic Methods

The ergonomics methods were created to measure the risk factors according to the necessities or work environment of employers. There are many techniques to study occupational health and safety and measure musculoskeletal disorders, postures, and exposure. Some of them are observational methods, direct measurements, or data recorded by media or sensors (David, 2005).

Each ergonomic method evaluates a specific body part or a type of job. These calculated the ergonomic risk level and give recommendations of how to improve the performance of the worker, work environment and reduce the medical problems.

In the table 2 are the principal and most uses ergonomic methods according to the biomechanical lab ERGONAUTAS of the "Universidad Politécnica de Valencia" in Spain.

Table 2 Ergonomic Methods

Groups	Method	Main Feature	Reference
Forces and Biomechanics	Applied Forces	Evaluates the risk derived from exerting forces	(Mas & Antonio, 2019)
	Biomechanical Analysis	Performs biomechanical evaluations of static stresses based on the posture adopted, the load and the frequency and duration of the stresses	(Mas & Antonio, 2015a)
Repetitiveness	OCRA	Allows rapid assessment of the risk associated with repetitive movements of the upper limbs	(Mas & Antonio, 2015c)
	JSI	Assesses the risks related to the upper extremities and provides a numerical output	(Mas & Antonio, 2015f)
Postural Load	RULA	Evaluate the exposure of workers to risks due to improper posture of the upper body members	(Mas & Antonio, 2015e)
	REBA	Assesses the exposure of workers to risk factors that can cause cumulative traumatic disorders due to dynamic and static postural loading	(Mas & Antonio, 2015d)
	OWAS	Ergonomic analysis of the postural load in the observation of different postures	(Mas & Antonio, 2015l)
	EPR	Assesses the overall postural load throughout the workday	(Mas & Antonio, 2015h)
Cargo Management	NIOSH	Identify the risks related to manual load lifting tasks	(Mas & Antonio, 2015b)

	SNOOK and CIRIELLO	Allow the determination of the maximum acceptable weights for different stocks	(Mas & Antonio, 2015m)
Office Positions	ROSA	Allows quantification of the ergonomic risk associated with office workstations.	(Mas & Antonio, 2015k)
Global Evaluation	LCE	Checklist of ergonomic principles that proposes simple and low-cost ergonomic interventions.	(Mas & Antonio, 2015g)
	LEST	Evaluates working conditions both physically and in terms of mental workload and psychosocial aspects.	(Mas & Antonio, 2015j)
Thermal Environment	FANGER	Evaluates the thermal conditions of those present in a thermal environment determined by their physical form as well as by the mental load and psychosocial aspects.	(Mas & Antonio, 2015i)

In the table 3, David Geoffrey (David, 2005) exposure the principal risk factors assessed by different methods.

Table 3 Ergonomic methods vs Risk factors. Own elaboration from (David, 2005)

Technique	**Posture**	**Load / Force**	**Movement Frequency**	**Duration**	**Recovery**	**Vibration**	**Others ***
OWAS	x	x					
OCRA	x	x	x	x	x	x	x
RULA	x	x	x				
NIOSH	x	x	x	x	x		x
REBA	x	x	x				x
JSI	x	x	x	x			x

* These include, mechanical compression, glove use, environmental conditions, equipment, load coupling, teamwork, visual demands, psychosocial and individual factors.

2.1.5. Ergonomics in Medicine

Several biomechanical investigations in patients and medical staff have been carried out in hospitals. However, these investigations have not priority in health care workers which causes a decrease in efficiency of the health care system. The occupational safety department in the development of diagnostics and the search for improvement options has begun to realize regular ergonomic analyses in nurses, surgeons, doctors, laboratorians, and administrative workers.

Henriquez (Henríquez, 2014) showed that the most risk factors are physic load, musculoskeletal disorders, shift systems, mental workload, and overall workload. These factors are due to the patient's management, critical patient unit personnel and principally that medicine is a primordial and active job. The ergonomics evaluations are of great impact on the health, social life, and performance of the medical staff, in order to improve the health sector.

It should be clarified that ergonomics evaluations of medical staff in Ecuador and other Latin American countries are scarce or lacking in some departments, the same that are decreasing the efficiency and efficacy in the services.

2.1.6. Musculoskeletal Disorders

A lot of investigations such as (Buckle, 2005) and (David, 2005) focus on studying the causes of musculoskeletal disorders (MSDs) for preventing these ones. In all types of companies and workplaces, employers are prone to suffer MSDs, for this reason, ergonomics interventions are a primary prevention.

MSDs are the mayor source of disability and lost work time, especially in workers with an extreme postures, loads, or movements. In addition, these problems reduce the productivity of the company and the effectiveness of the work, aside from the future medical complications (Buckle, 2005).

The most common complications in healthcare workers are in the back, shoulder, and neck due to excessive forces and awkward postures during patient care, pushing or pulling objects and working long hours. The job cycles and workers in clinical areas, such as emergency services, critical care, operating rooms, or orthopedic unit, are more exposed to occupational risk factors (Waters et al., 2006).

(Iturralde, 2014) in his study about MSDs in Ecuador shows that the most common injuries are in the lower back caused by cumulative trauma, forcing the loss of working time and resulting in costly for the employer. Other of the frequent disorders are:

Table 4 Frequent Disorders in different body parts

Injuries	Frequent Disorders
Neck	Cervical sprain, cervical tension syndrome and cervical spondylosis.
Shoulder	Subacromial bursitis, tendonitis, and rotator cuff condition.
Spinal	Herniated disc, sciatic nerve injury and lumbago.
Knee	Bursitis and knee arthritis.

2.1.7. Ergonomic Risk in Laparoscopic Surgery

Laparoscopic surgery is a minimally invasive intervention that offers very advantages for patients but, some disadvantages for surgeons. For the patients, least damage to the tissues, rapid recovery, and short procedure time. However, the surgeons encounter difficulties that were not present during open surgical procedures. These difficulties include two-dimensional viewing of the three-dimensional surgical, field, and awkward instruments with force transmission properties inferior to their open surgical (Berguer et al., 1999). As result, mental and physical fatigue due to indirect intervention, that is, there is a substitution of hands and direct eye contact to the body of patients with specific instruments and monitors giving way to inadequate postures (Jurado & Gonzalez, 2015).

Many factors influence in the risk ergonomic of surgeon during laparoscopic interventions such as high degree of precision and coordination, poor layout of the workstation, repetitive motions and static postures that increase the musculoskeletal injuries (Jurado & Gonzalez, 2015).

2.1.8. Importance of Ergonomic Studies

Since the emergence of modern ergonomics, after World War I, its three principal aims have always been to improve health and welfare, reduce de accidents and musculoskeletal disorders and enhance the company performance (APUD & MEYER, 2003). But, why, several years after its creation, currently is being implemented in health professionals? Although ergonomics emerged many years ago, its development and use in health care professionals are recent, due to the new regulations implemented in each country that protects the workers and the born on occupational safety.

After the industrial engineering revolution, with the research of new tools, job positions, or equipment in companies, ergonomics has increased the quality of products

and services provided, due to, this science integrates the worker with the devices and makes them adapt to the work environment. That is, when any activity is included, that will have human participation, the effects of human-environment interaction should be assessed (APUD & MEYER, 2003).

According to The International Labour Organization (ILO), the 80% of workers, during their work life, had or will have at least one musculoskeletal disorder. Also, MSDs are the second leading cause of absenteeism worldwide(Niu, 2010). This high prevalence of MSDs gives us a better vision of the importance of ergonomics studies. Other relevance dates are:

- 1710 millions of people approx. have MSDs around the world (WHO, 2021).
- The prevalence of mortality and morbidity due to occupational causes in each continent are: 65% in Asia, 11.8% in Africa, 11.7% in Europe, 10.9% in America and 0.6% in Oceania (ILO, 2019).
- In Great Britain, the health sector is among the highest sectors exposed to physical risks combined with ambient, biological, and chemical risks(Adisesh, n.d.).
- Some European countries: In Germany, 37% showed back and lumbar pain, 29% neck and shoulder pain and 13% of arms and hands. In Spain, 69.2% stated back and lumbar problems of work-related pain. In Italy, in an investigation un 54 hospitals, the 8.4% of workers reported having suffered pain within a 12-month period(Agencia Europea para la Seguridad y la Salud en el Trabajo, 2000).

In Ecuador like others Latin American countries has a deficiency in the development of ergonomic studies, therefore the data of work-related musculoskeletal problems is scare. Nevertheless, a study realized of medical and nursing staff in “Hospital San Vicente de Paul” at Ibarra showed that the prevalence of MSDs is 78% with respect to pain and 75.4% correspond to aches. This is a high prevalence in the population studied a consequence of work(Cabrera, 2015).

The “Sociedad Científica Ecuatoriana de Ergonomía” was linked to “Unión Latinoamericana de Ergonomía” with members from the following countries: Cuba, Colombia, Venezuela, Ecuador, Uruguay, Brazil, Peru, Argentina, and Chile. In 2015, 30 Ecuadorian members reported within the association, however in the current year the active members decrease to 17, which denotes a significant loss in the ergonomic studies(Albrecht, 2016)(SOCEERGO, 2021).

2.1.9. Regulations

From the first world war, with the rise of the industrial revolution, appears the first regulations in ergonomics that include methods and criteria to prevent occupational hazards. Due to this discipline, each country began to implement new regulations, to help the employer in adapting to the job and by this way improve the occupational safety in the companies.

Some international regulations are:

- In 1967, the International Labour Organization (ILO) show some recommendations about the maximum loads and the way to use them (Vedder & Laurig, 2010).
- The NIOSH guides about weightlifting, propose the limits of loads how a postural element (Vedder & Laurig, 2010).
- In the regulations and guidelines about ergonomics, in the European community and International Organization for Standardization (ISO), include aspect about postural elements (Vedder & Laurig, 2010).
- Spain has three royal decrees (486, 773 and 1215) upon the good work places, the use of personal protective equipment and use of work teams (Del Prado, 2019).

At a national level, being a free and democratic country, there are agencies and corporations that guarantee compliance with regulations and employers' rights. Ecuador includes international and national regulations that are dedicated to protecting employers, optimizing productivity and reduce the high costs due to musculoskeletal problems work-related. Some legislations are:

- The Article 410 of the Work Code says: "Obligaciones respecto de la prevención de riesgos. - Los empleadores están obligados a asegurar a sus trabajadores condiciones de trabajo que no representen peligro para su salud o su vida. Los trabajadores están obligados a acatar las medidas de prevención, seguridad e higiene determinadas en los reglamentos y facilitadas por el empleador. Su omisión constituye justa causa para la terminación del contrato de trabajo" (Asamblea Nacional, 2012).
- The Article 326, number 5 of Ecuador Constitution says: "Toda persona tendrá derecho a desarrollar sus labores en un ambiente adecuado y propicio, que garantice su salud, integridad, seguridad, higiene y bienestar." (Asamblea Nacional, 2008)
- The Article 2, number 2 of Worker Health and Safety and Work Environment Improvement Regulation created by "Instituto Ecuatoriano de Seguridad Social"

(IESS, 2012) indicates: “Vigilar el mejoramiento del medio ambiente laboral y de la legislación relativa a prevención de riesgos profesionales, utilizando los medios necesarios y siguiendo las directrices que imparta el Comité Interinstitucional.”

- The “Instituto Ecuatoriano de Normalización” is the entity responsible to approve the ISO regulations according to the necessities of the country. Some ISO regulations of ergonomics accepted are: INEN-ISO 11226 (Instituto Ecuatoriano de Normalización, 2014a) for static working postures, INEN-ISO 11228 - 1 (Instituto Ecuatoriano de Normalización, 2014b) of manual lifting and transporting of loads, INEN-ISO 11228 - 2 (Instituto Ecuatoriano de Normalización, 2014c) of pushing and pulling of loads and INEN-ISO 11228 - 3 (Instituto Ecuatoriano de Normalización, 2014d) of repetitive movements.

2.1.10. Socioeconomic Costs

The socioeconomic costs are important to prevent the MSDs or incorporate workers who suffer any type of these problems. Such costs can include medical and rehabilitation costs, loss and transfer of income, the cost for companies, loss of quality of life or general well-being, and other variables about the interventions of the working life(Agencia Europea para la Seguridad y la Salud en el Trabajo, 2000). However, the total cost varies greatly depending on the country and its socioeconomic analysis.

The Gross National Product (GNP) designates the total production of all economic units of a nation during a specific period, generally 1 year (Nichols & Reynolds, 1971). Each country has different percentage of GNP for the musculoskeletal diseases. For example:

- In Great Britain, the total annual cost of work-related MSDs ranged from 5.6 to 5.8 billion pounds sterling, equivalent to 0.79-0.82% of British GNP (Agencia Europea para la Seguridad y la Salud en el Trabajo, 2000).
- In Germany, the losses due to work-related MSDs reach a high rate of 0.61% of GNP, equivalent to DM 23 billion(Agencia Europea para la Seguridad y la Salud en el Trabajo, 2000).
- In Finland, the total cost of MSDs is estimated at FIM 5.7 billion, representing 1% of GNP(Agencia Europea para la Seguridad y la Salud en el Trabajo, 2000).
- In Colombia, 171.7 US million was the total cost for MSD cases about workers' productivity, representing 0.2% of GNP (Piedrahita, 2006).
- In United States, the total costs of work-related MSDs during the period 2003 to 2007 declined, but the costs per case went up, so the medical and other costs increased (Bhattacharya, 2014).

These investments of GNP for MSDs are crucial, due to in not all countries exist any type of money destined for MSDs. However, according to the data collected, the increase or decrease of GNP can be good or bad depending on which variable changed.

2.2. Related Works for Ergonomic Evaluation of Surgeons

A list of ergonomics papers related to the present work is shown in the table 5. These studies were carried out on surgeons with different ergonomic methods.

Table 5 A list of ergonomics papers related to the present work

#	Paper	Objective of Study	Citation
1	Ergonomics and gynecologic laparoscopic surgery	Prospective study on ergonomic evaluation and laparoscopic surgery performed by gynecologists.	(Allendes et al., 2020)
2	Ergonomics in laparoscopic surgery and its importance in surgical training in surgical training	Provide the surgeon with ergonomic guidelines for body positioning and equipment placement. In addition, present the training model based on ergonomic criteria, applied in the training activities in laparoscopic surgery, carried out in our Center.	(Pérez-Duarte et al., 2012)
3	Ergonomic Study of the Surgeon During Open and Laparoscopic Cholecystectomy	Determine the postural load of laparoscopic cholecystectomy and compare it with open cholecystectomy, to establish the level of risk of musculoskeletal injury and to seek ergonomic solutions to improve the surgeon's comfort and the efficiency of the surgical procedure.	(álvarez et al., 2002)
4	Ergonomy related pain in arthroscopist surgeons	Establish the prevalence of musculoskeletal osteomuscular pain in orthopedic surgeons performing arthroscopy	(Nicolás Prada Ramírez et al., n.d.)
5	Level of occupational risk in dental surgeons of the Directorate of Integrated Health Networks Lima Norte, 2018.	Describe the level of occupational risk in Dental Surgeons working in the Directorate of Integrated Health Networks Lima Norte, 2018.	(Flores & Alberca, 2019)
6	Musculoskeletal pain associated with ergonomic postures adopted by 9th semester students of the UTEA	Associate musculoskeletal pain and ergonomic postures adopted by 9th semester students of the Specialized Dental Clinic of the Universidad Tecnológica de los Andes.	(Pichihua & Oscco, 2019)

CHAPTER 3

3.1. MATERIALS AND METHODS

Ergonomics seeks to create a match between the work environment and man, i.e., to measure man's capabilities and then arrange the environment to fit them. So, choosing the right tools is primordial to the development of the ergonomic systems.

The corresponding materials and methods are described below.

3.1.1. Ergonomic Methods

3.1.1.1. RULA method

The Rapid Upper Limb Assessment (RULA) method was created by McAtamney and Corlett in the Institute for Occupational Ergonomics with the objective of evaluated the postural load and the disorders of workers (Mas & Antonio, 2015e). This method studies the development of a posture and investigates the risk factor associated with upper limb disorders according to the posture adopted forces required, and muscle actions. (Mcatamney & Corlett, 1993)

RULA method uses body postures diagrams and scoring tables to evaluate the risk factors. The factors in consideration are several movements, statics muscle work, force, work postures determined by the equipment and furniture, and time worked without a break. In addition, other individual factors such as age, experience, workplace environment are important to detect ergonomic problems. This tool no needs any special equipment, so it provides more opportunities to investigators (Mcatamney & Corlett, 1993).

This method occurs in three phases:

1. Record the working position.
2. Scoring system.
3. Scale of action levels (Mcatamney & Corlett, 1993).

The body is divided into two groups. Group A includes arms, forearms, and wrists, and group B includes legs, trunk, and neck (Mas & Antonio, 2015e). First, the postures and individual factors are identified and record. Then, the body parts are scored according to the figures and tables are shown following.

Group A

Arms

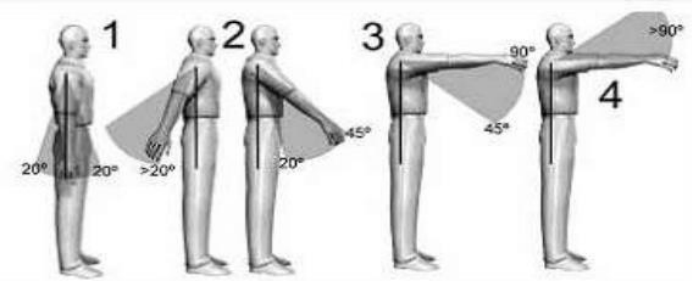


Figure 1 Arm positions (Mas & Antonio, 2015e)

Table 6 Arm Score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	**Punctuation**
From 20° of extension to 20° of flexion	1
Extension >20° or flexion between 20° and 45°	2
Flexion between 45° and 90°	3
Flexion >90°	4

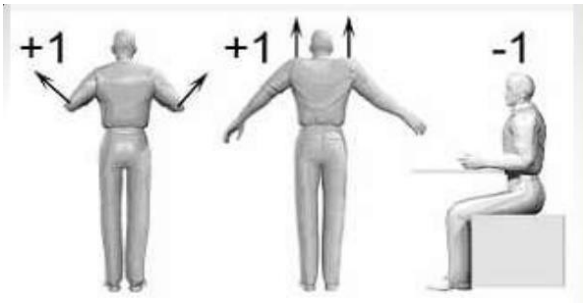


Figure 2 Positions that modify the arm score (Mas & Antonio, 2015e)

Table 7 Modifications of arm score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	**Punctuation**
If the shoulder is elevated or the arm rotated	+1
If the arms are abducted	+1
If the weight of the arm is supported	-1

Forearms

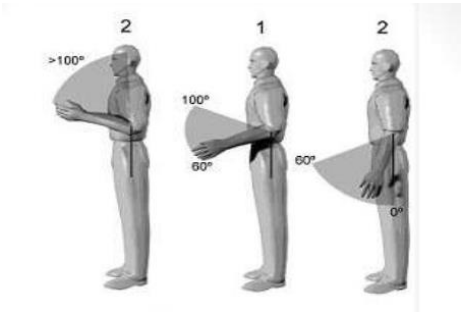


Figure 3 Forearm positions (Mas & Antonio, 2015e)

Table 8 Forearm score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	Punctuation
Flexion between 60° and 100°	1
Flexion <60° or >100°	2

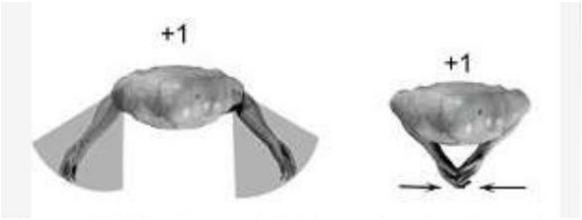


Figure 4 Positions that modify the forearm score (Mas & Antonio, 2015e)

Table 9 Modifications of forearm score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	Punctuation
If the forearm is working out to the side.	+1
If the forearm is working across the midline of the body.	+1

Wrists

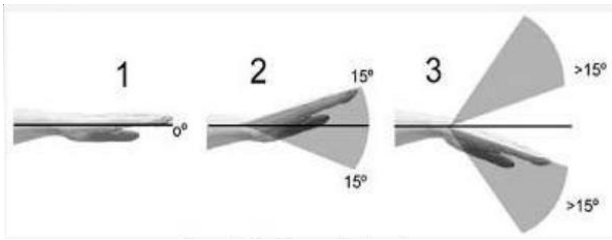


Figure 5 Wrist Positions (Mas & Antonio, 2015e)

Table 10 Wrist score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	Punctuation
If in a neutral position	1
For 0 – 15° in either flexion or extension	2
For 15° or more in either flexion or extension	3

Figure 6 Wrist deviation (Mas & Antonio, 2015e)

Table 11 Modifications of wrist score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	Punctuation
If the wrist is in either radial or ulnar deviation	+1

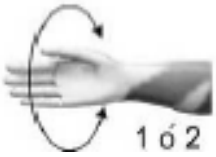


Figure 7 Twist of the wrist (Mas & Antonio, 2015e)

Table 12 Twist of the wrist score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	Punctuation
If the wrist is in mid-range of twist	1
If the wrist is at or near the end of range of twist.	2

Group B

Legs

Figure 8 Legs positions (Mas & Antonio, 2015e)

Table 13 Legs score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	Punctuation
If the legs and feet are well supported when seated with weight evenly balanced	1
If standing with the body weight evenly distributed overboth feet, with room for changes of position	1
If the legs and feet are not supported or the weight is unevenly balanced	2

Trunk

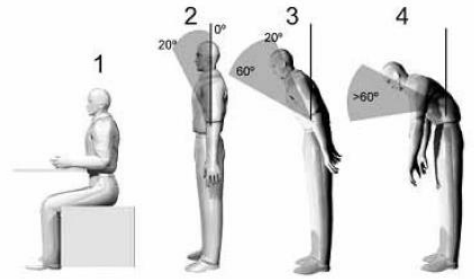


Figure 9 Trunk positions (Mas & Antonio, 2015e)

Table 14 Trunk score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	Punctuation
When sitting and well supported with a hip-trunk angle of 90° or more	1
For 0 – 20° flexion	2

For 20° - 60° flexion	3
For 60° or more flexion	4

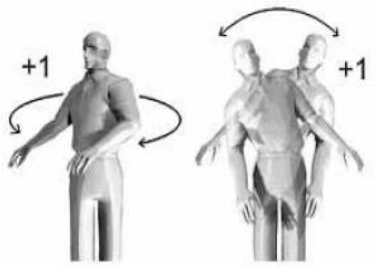


Figure 10 Positions that modify the trunk score(Mas & Antonio, 2015e)

Table 15 Modifications of trunk score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	Punctuation
If the trunk is twisting	+1
If the trunk is in side-bending	+1

Neck

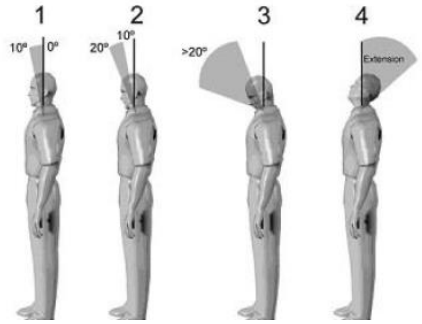


Figure 11 Neck positions(Mas & Antonio, 2015e)

Table 16 Neck score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	Punctuation
For 0 – 10° flexion	1
For 10° - 20° flexion	2
For 20° or more flexion	3
If in extension	4

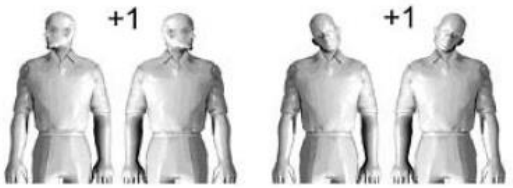


Figure 12 Positions that modify the neck score(Mas & Antonio, 2015e)

Table 17 Modifications of neck score. Own elaboration from (Mcatamney & Corlett, 1993)

Position	Punctuation
If the neck is twisted	+1
If the neck is in side-bending	+1

The last phase consists in obtain the global punctuations of both groups plus type of activity and force or load, final punctuation, and action level, according to the tables following. All these aspects indicate how act to improve the workstation.

Group A score

Table 18 Groups A score. Own elaboration from (Mas & Antonio, 2015e)

Arm	Forearm	Wrist							
		1		2		3		4	
		Twist of wrist		Twist of wrist		Twist of wrist		Twist of wrist	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	3	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	5	5	5	5
	2	4	4	4	5	5	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7

	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	**1**	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Group B score

Table 19 Group B score. Own elaboration from (Mas & Antonio, 2015e)

Neck	**Trunk**											
	1		**2**		**3**		**4**		**5**		**6**	
	Legs		**Legs**		**Legs**		**Legs**		**Legs**		**Legs**	
	1	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Type of activity

Table 20 Type of activity score. Own elaboration from (Mcatamney & Corlett, 1993)

Type of activity	**Punctuation**
Mainly static, eg held for longer than 1 min	+1
Repeated more than 4 times/min	+1
Occasional, short duration	0

Force or load

Table 21 Forces or load score. Own elaboration from (Mcatamney & Corlett, 1993)

Load or force	**Punctuation**
No resistance or less than 2kg, intermittent load or force	0
2 – 10 kg intermittent load or force	+1
2 – 10 kg static load	+2

2 -10 kg repeated load or force	+2
10kg or more static or repeated load or forces	+3
Shock or forces with a rapid build-up	+3

Final Punctuation

Table 22 Final score. Own elaboration from (Mas & Antonio, 2015e)

Score C	Score D						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8	5	5	6	7	7	7	7

Action Levels

Table 23 Action levels. Own elaboration from (Mcatamney & Corlett, 1993)

Punctuation	Level	Action
1 or 2	1	Posture is acceptable if it is not maintained or repeated for long periods.
3 or 4	2	Further investigation is needed, and changes may be required.
5 or 6	3	Investigation and changes are required soon.
7	4	Investigation and changes are required immediately.

3.1.1.2. REBA method

The Rapid Entire Body Assessment (REBA) method, by Hignett and McAtamney, was created applying the previous methods such as the NIOSH equation, OWAS method, BPD technique, Effort Perception Scale, and RULA method; with the objective of evaluating the risk level of a worker due to the adoption of inadequate postures (Mas & Antonio, 2015d). This method studies the entire body in individual postures, especially in tasks that have unexpected changes of postures or unstable loads. Its application is in musculoskeletal injured, required minimal equipment, and is very used in health care and other industries (Hignett & Mcatamney, 2000).

REBA method uses body postures diagrams and scoring tables to evaluate the risk factors. The factors in consideration are different postures, load, force, grip type, and type of activity develop by the worker (Mas & Antonio, 2015d). Other individual factors are analyzed such as age, experience, and workplace environment.

The development of the REBA tool begins by defining the job cycles and body postures that will be recorded. The body is divided into two groups. Group A includes legs, trunk, and neck, and group B includes Arms, forearms, and wrists (Mas & Antonio, 2015d). Then, the body parts are scored according to the figures, and tables are shown following.

<u>Group A</u>

Trunk

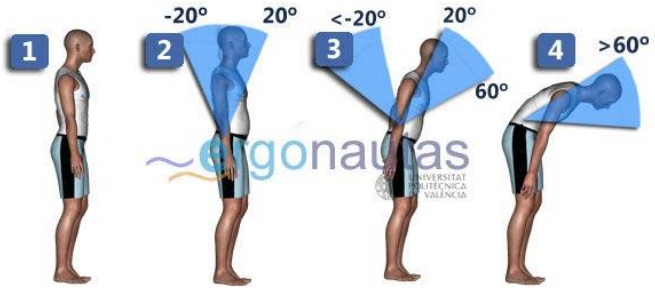


Figure 13 Trunk positions(Mas & Antonio, 2015d)

Table 24 Trunk score. Own elaboration from (Hignett & Mcatamney, 2000)

Position	Punctuation
Upright	1
0 - 20° flexion or extension	2

20° - 60° flexion or >20° extension	3
>60° flexion	4

Figure 14 Positions that modify the trunk score*(Mas & Antonio, 2015d)*

Table 25 Modifications of trunk score. Own elaboration from *(Hignett & Mcatamney, 2000)*

Position	Punctuation
If twisting or side flexed	+1

Neck

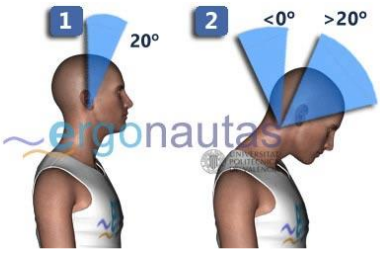


Figure 15 Neck positions*(Mas & Antonio, 2015d)*

Table 26 Neck score. Own elaboration from *(Hignett & Mcatamney, 2000)*

Position	Punctuation
0° - 20° flexion	1
>20° flexion or in extension	2

Figure 16 Positions that modify the neck score*(Mas & Antonio, 2015d)*

Table 27 Modifications of neck score. Own elaboration from (Hignett & Mcatamney, 2000)

Position	Punctuation
If twisting or side flexed	+1

Legs

Figure 17 Legs positions(Mas & Antonio, 2015d)

Table 28 Legs score. Own elaboration from (Hignett & Mcatamney, 2000)

Position	Punctuation
Bilateral weight bearing, walking, or sitting	1
Unilateral weight bearing. Feather weight bearing or an unstable posture	2

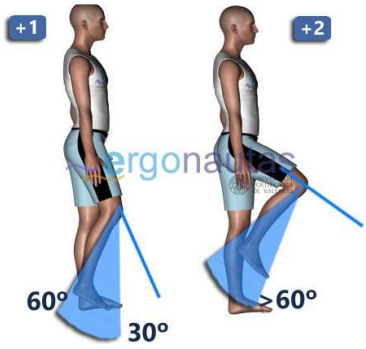


Figure 18 Positions that modify the legs score(Mas & Antonio, 2015d)

Table 29 Modifications of legs score. Own elaboration from (Hignett & Mcatamney, 2000)

Position	Punctuation
If knee(s) between 30° and 60° flexion	+1
If knee(s) are >60° flexion	+2

Group B

Arms

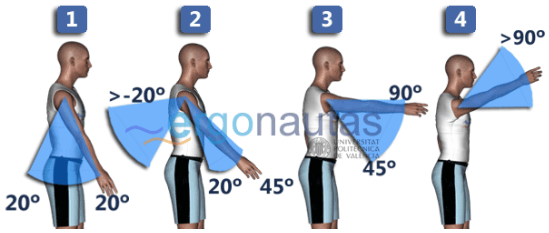


Figure 19 Arm positions(Mas & Antonio, 2015d)

Table 30 Arm score. Own elaboration from (Hignett & Mcatamney, 2000)

Position	Punctuation
20° extension to 20° flexion	1
>20° extension or 20° - 45° flexion	2
45° - 90° flexion	3
>90° flexion	4

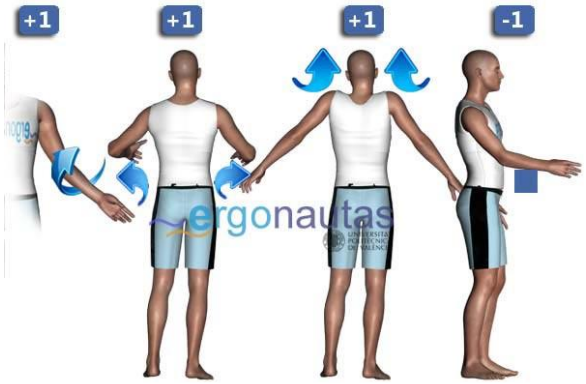


Figure 20 Positions that modify the arm score

Table 31 Modifications of arm score. Own elaboration from (Hignett & Mcatamney, 2000)

Position	Punctuation
If arm is abducted or rotated	+1
If shoulder is raised	+1
If leaning supporting weight of arm or if posture is gravity assisted	-1

Forearms

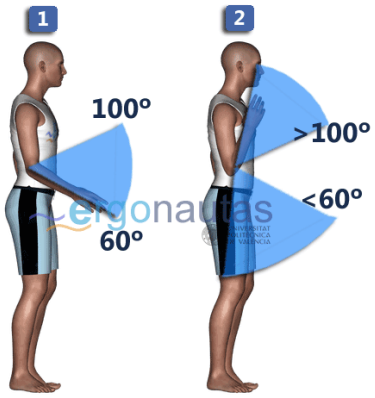


Figure 21 Forearm positions(Mas & Antonio, 2015d)

Table 32 Forearm score. Own elaboration from (Hignett & Mcatamney, 2000)

Position	Punctuation
60° – 100° flexion	1
<60° flexion or >100° flexion	2

Wrists

Figure 22 Wrist positions(Mas & Antonio, 2015d)

Table 33 Wrist score. Own elaboration from (Hignett & Mcatamney, 2000)

Position	Punctuation
Neutral	1
0° - 15° flexion	1
>15° flexion or extension	2

Figure 23 Positions that modify the wrist score(Mas & Antonio, 2015d)

Table 34 Modifications of wrist score. Own elaboration from (Hignett & Mcatamney, 2000)

Position	Punctuation
If wrist is deviated or twisted	+1

The next step consists in obtain the global punctuations of group A plus force or load, the global punctuation of group B plus grip type, final punctuation plus type of muscle activity, and action level, according to the tables following.

Group A score

Table 35 Group A score. Own elaboration from (Mas & Antonio, 2015d)

Trunk	Neck											
	1				2				3			
	Legs				Legs				Legs			
	1	2	3	4	1	2	3	4	1	2	3	4
1	1	2	3	4	1	2	3	4	3	3	5	6
2	2	3	4	5	3	4	5	6	4	5	6	7
3	2	4	5	6	4	5	6	7	5	6	7	8
4	3	5	6	7	5	6	7	8	6	7	8	9
5	4	6	7	8	6	7	8	9	7	8	9	9

Table 36 Load or force score. Own elaboration from (Hignett & Mcatamney, 2000)

Load or Force	Punctuation
<5 kg	0
5-10 kg	+1
>10 kg	+2

Table 37 Sudden load or force. Own elaboration from (Hignett & Mcatamney, 2000)

Load or Force	Punctuation
Shock or rapid build up of force	+1

Group B score

Table 38 Group B score. Own elaboration from (Mas & Antonio, 2015d)

Arm	Forearm					
	1			2		
	Wrist			Wrist		
	1	2	3	1	2	3
1	1	2	2	1	2	3
2	1	2	3	2	9	4
3	3	4	5	4	5	5
4	4	5	5	5	6	7
5	6	7	8	7	8	8
6	7	8	8	8	9	9

Coupling

Table 39 Grip quality score. Own elaboration from (Hignett & Mcatamney, 2000)

Quality	Description	Punctuation
Good	Well-fitting handle and a mid-range, power grip	0
Fair	Hand hold acceptable but not ideal or coupling is acceptable via another part of the body	+1
Poor	Hand hold not acceptable although possible	+2
Unacceptable	Awkward, unsafe, grip no handles. Coupling is unacceptable using other parts of the body	+3

Figure 24 Grip quality types(Mas & Antonio, 2015d)

Final Punctuation

Table 40 Score C. Own elaboration from (Mas & Antonio, 2015d)

Punctuation A	Punctuation B											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Activity score

Table 41 Activity score. Own elaboration from (Hignett & Mcatamney, 2000)

Type of muscle activity	**Punctuation**
1 or more body parts are static, e.g., held for longer than 1 min	+1
Repeated small range actions, e.g., repeated more than 4 times per minute (not including walking)	+1
Action causes rapid large range changes in postures or an unstable base	+1

Action Levels

Table 42 Action levels. Own elaboration from (Hignett & Mcatamney, 2000)

Punctuation	**Level**	**Risk**	**Action**
1	0	Negligible	None necessary
2 or 3	1	Low	May be necessary
4 to 7	2	Medium	Necessary
8 to 10	3	High	Necessary soon
11 to 15	4	Very high	Necessary NOW

3.1.1.3. OCRA method

The Occupational repetitive Action (OCRA) was created by Occhipinti and Colombini with the objective of evaluated occupational risk factors associated with work-related musculoskeletal disorders of the upper limbs (Occhipinti, 1998). This method studies the index of exposure to repetitive movements that can be derivate in health problems in bones, muscles, joints, tendons, ligaments, and nerves(Mas & Antonio, 2015c).

OCRA method uses equations and scoring tables to evaluate the risk factors. The factors in consideration are static or inadequate postures, repeatability, forces, forced movements, lack of breaks or recovery periods, vibrations, exposure to cold, and job cycles (Mas & Antonio, 2015c). The application of the OCRA method is complicated, so the same authors created the Check List OCRA that is the shortcut. This check list permits obtain the risk level with less effort and is the most used tool to realize a first risk evaluation. It should be highlighted that this method is the gold standard of ergonomics.

The development of the method starts in determine the OCRA check list index (ICKL) from five factors, net duration of repetitive work (in minutes), and net totalcycle time (in seconds), according to the equations and tables are shown following.

- **Net duration of repetitive work (TNTR)**

$$TNTR = duration\ of\ shift - \ (Non - repetitive\ work + Breaks + Lunch\ Break)$$

Equation 1 Net duration of repetitive work. Own elaboration from (Mas & Antonio, 2015c)

- **Net totalcycle time (TNC)**

$$TNC = \frac{60 * TNTR}{Number\ of\ cycles}$$

Equation 2 Net totalcycle time. Own elaboration from (Mas & Antonio, 2015c)

- **OCRA Checklist index (ICKL)**

$$ICKL = \begin{pmatrix} Recovery\ time + Frequency + Force + Posture \\ + Additional\ factors \end{pmatrix} * Duration\ Multipliere$$

Equation 3 Checklist index. Own elaboration from (Mas & Antonio, 2015c)

Recovery time factor (FR)

Table 43 Recovery time factor score. Own elaboration from (Mas & Antonio, 2015c)

FR	Punctuation
Interruption of at least 8 minutes every working hour. The recovery period is included in the work cycle.	0
There are at least 4 breaks (in addition to the lunch break) of at least 8 minutes in a 7–8-hour shift. There are 4 breaks of at least 8 minutes in a 6-hour shift (no lunch break).	2
There are 3 breaks, of at least 8 minutes, plus a lunch break, in a 7–8-hour shift. There are 2 breaks, of at least 8 minutes, in a 6-hour shift (no lunch break).	3
There are 2 breaks, of at least 8 minutes, in addition to the lunch break, in a 7–8-hour shift. There are 3 breaks (without lunch break), of at least 8 minutes, in a 7–8-hour shift. There is 1 break, of at least 8 minutes, in a 6-hour shift.	4
There is 1 break, of at least 8 minutes, in a 7-hour shift without a lunch break. In 8 hours, there is only a lunch break (lunch break is included in working hours).	6
There are no real breaks, except for a few minutes (less than 5) in a 7–8-hour shift.	10

Frequency Factor (FF)

$$FF = Max\ (ATD; ATE)$$

Equation 4 Frequency factor. Own elaboration from (Mas & Antonio, 2015c)

Specifications:

Technical Action	These are not technical actions
• Move • Reach • Grab • Put • Insert/remove • Take each other's hand • Push/pull • Put into operation • Transport	• Release • Walk • Visual control • Technical actions that do not involve any activity of the upper extremity.

Figure 25 Specifications of frequency factor. Own elaboration from (Mas & Antonio, 2015c)

Table 44 Dynamic technical actions score. Own elaboration from (Mas & Antonio, 2015c)

Dynamic technical actions	**ATD**
Arm movements are slow (20 actions/minute). Frequent short pauses are allowed.	0
Arm movements are not too fast (30 actions/minute). Small pauses are allowed.	1
Arm movements are quite fast (more than 40 actions/minute). Small pauses are allowed.	3
Arm movements are quite fast (more than 40 actions/minute). Only occasional and irregular small pauses are allowed.	4
Arm movements are fast (more than 50 actions/minute). Only occasional and irregular small pauses are allowed.	6
Arm movements are rapid (more than 60 actions/minute). The lack of pauses makes it difficult to maintain the rhythm.	8
Arm movements are performed with a high frequency (70 actions/minute or more). Pauses are not allowed.	10

Table 45 Static technical actions score. Own elaboration from (Mas & Antonio, 2015c)

Static technical actions	**ATE**
Relative duration intervals for greater than 50% to 80%	2.5

Relative duration intervals for greater than 80%	4.5

Force factor (FFz)

First, the actions that require the use of force are identified, such as push buttons, close or open, push or pull levers, use tools, lifting or holding objects or Handle or tighten components.

Table 46 OCRA FFz score. Own elaboration from (Mas & Antonio, 2015c)

Effort	**Punctuation**	**OCRA FFZ**
Null	0	It is not considered
Very weak	1	
Weak	2	
Moderate	3	Moderate force
	4	
Hard	5	Heavy level
	6	
Very Hard	7	
Close to maximum	8	Extremely heavy
	9	
	10	

Table 47 Force score. Own elaboration from (Mas & Antonio, 2015c)

Moderate force		**Heavy level**		**Extremely heavy**	
Duration	Punctuation	Duration	Punctuation	Duration	Punctuation
1/3 of time	2	2 sec. each 10 min.	4	2 sec. each 10 min.	6
50% of time	4	1% of time	8	1% of time	12
>50% of time	6	5% of time	16	5% of time	24

most of the time	8	>10% of time	24	>10% of time	32

Posture factor (FP)

$$FP = Max\ (PHo; PCo; PMu; PMa) + PEs$$

Equation 5 Posture factor. Own elaboration from (Mas & Antonio, 2015c)

Table 48 Shoulder score. Own elaboration from (Mas & Antonio, 2015c)

Shoulder	**PHo**
The arm is unsupported and remains slightly elevated for more than half the time	1
The arms are kept at about shoulder height, without support, for: 10% - 24% of the time	2
25% - 50% of the time	6
51% - 80% of the time	12
More than 80% of the time	24

Table 49 Elbow score. Own elaboration from (Mas & Antonio, 2015c)

Elbow	**PCo**
The elbow executes sudden movements for: 25% - 50% of the time	2
51% - 80% of the time	4
More than 80% of the time	8

Table 50 Wrist score. Own elaboration from (Mas & Antonio, 2015c)

Wrist	**PMu**
The wrist must bent in an extreme position, or must keep awkward postures for: 25% - 50% of the time	2
51% - 80% of the time	4

More than 80% of the time	8

Table 51 Hand score. Own elaboration from (Mas & Antonio, 2015c)

Hand	**PMa**
The hand takes objects or tools in pinch, hook grip, pinch or other different kinds of grasp for: 25% - 50% of the time	2
51% - 80% of the time	4
More than 80% of the time	8

Table 52 Stereotypy movements score. Own elaboration from (Mas & Antonio, 2015c)

Stereotypy movements	**Pes**
The cycle time is between 8 and 15 seconds or identical technical actions are performed for 2/3 of the time	1.5
The cycle time is less than 8 seconds or identical technical actions are performed almost the entire time	3

Additional factors (FC)

$$FC = Ffm + Fso$$

Equation 6 Additional factors. Own elaboration from (Mas & Antonio, 2015c)

Table 53 Socio-organizational factors score. Own elaboration from (Mas & Antonio, 2015c)

Socio-organizational factors	**Fso**
The work rate is determined by the machine, but 'recovery spaces' exist allowing the rate to be sped up or slowed down.	1
The work rate is entirely determined by the machine.	2

Table 54 Physico-mahcanical factors score. Own elaboration from (Mas & Antonio, 2015c)

Physico-mechanical factors	**Ffm**
Inadequate gloves are used more than half the time for the task.	2

Presence of 2 or more sudden, jerky movements per minute.	2
Presence of at least 10 repeated impacts per hour	2
Contact with cold surfaces or performance of tasks in cold chambers for more than half the time.	2
Use of vibrating tools at least one third of the time. Assign a score of 4 if these tools involve a high degree of vibration	2
Tools are used that cause compression of muscle and tendon structures	2
More than half the time is spent performing precision tasks, requiring the worker to be physically close to see.	2
More than one additional factor is present at the same time for more than half the time.	2
One or more additional factors are present almost the entire cycle.	3

Duration multiplier (MD)

Table 55 Duration multiplier score. Own elaboration from (Mas & Antonio, 2015c)

TNTR	MD
60 - 120	0.5
121 - 180	0.65
181 - 240	0.75
241 - 300	0.85
301 - 360	0.925
361 - 420	0.95
421 - 480	1
481 - 539	1.2
540 - 599	1.5
600 - 659	2
660 - 719	2.8
≥ 720	4

The ICKL show the risk level, OCRA index and Action recommended with the next table.

Table 56 Action levels. Own elaboration from (Mas & Antonio, 2015c)

ICKL	**Risk Level**	**Action**	**OCRA index**
≤ 5	Optimal	Not required	≤ 1.5
5.1 - 7.5	Acceptable	Not required	1.6 - 2.2
7.6 - 11	Borderline or very low	A new analysis or improvement of the position is recommended	2.3 - 3.5
11.1 - 14	Low	Recommended job upgrading, medical supervision and training	3.6 - 4.5
14.1 - 22.5	Medium	Recommended job upgrading, medical supervision and training	4.6 - 9
>22.5	High	Recommended job upgrading, medical supervision and training	>9

3.1.2. Instrumentation

The material used in the investigation was:

- Computer
- Camera
- Camera tripod
- Cellphone
- KINOVEA software
- NORDIC questionnaire (in annex 1)
- REBA Field sheet (in annex 2)
- RULA Field sheet (in annex 3)
- OCRA Field sheet (in annex 4)

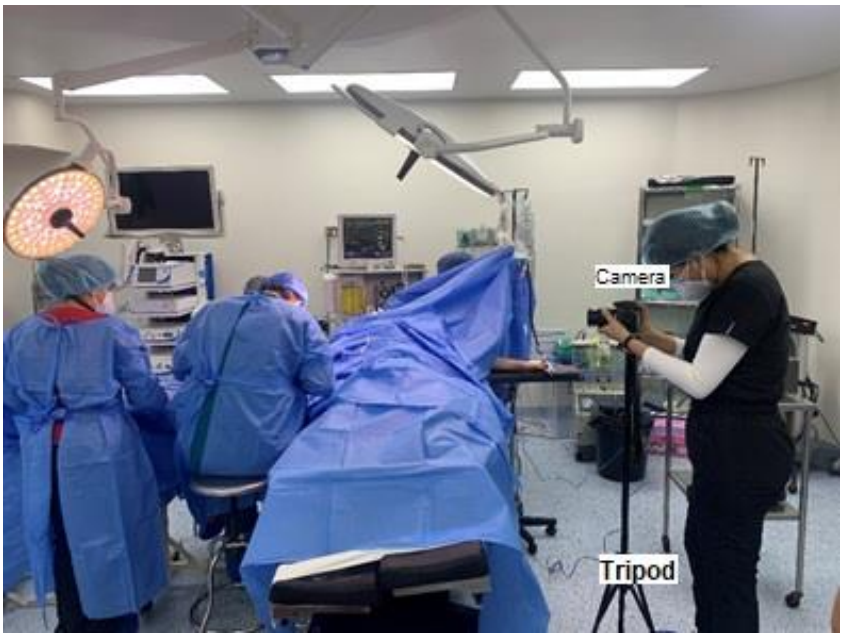


Figure 27 Instrumentation in operating room

Figure 26 Instrumentation

3.1.2.1. Kinovea Software

Kinovea is a free software application for the analysis, comparison, and evaluation of body movements. The advantages of this program are observation, measurement, comparison of videos, ease to use, and the analysis without the use of physical sensors(Guzman et al., 2013). This tool is very useful and important for ergonomics in different areas such as medicine, sports, or industry.

According to the Kinovea Organization (Kinovea Organization, n.d.), the main features of the software are:

- Observation: slow time down, zoom, rotate, mirror, deinterlace.
- Annotation: comments, labels, numbers, lines, arrows, curves, and drawings.
- Measurement: chronometer, distance, plot, and angles to increase the precision.
- Capture: capture and record camera streams. Hardware support for different inputs.
- Export: the annotations, photos, and videos can be saved in different files such as XML., PNG., JPG., or CSV.

3.1.2.2. Nordic Questionnaire

The Nordic questionnaire was created by Kuorinka and "Nordic group" in 1987. The aim of this questionnaire is a standard group of questions for the detection and analysis of musculoskeletal symptoms (Ibacache, n.d.). This tool is too important to prevent the MSDs and complaints the low back, neck, shoulder and other clinical diagnosis(Crawford, 2007).

The questionnaire is used in an interview were the patient report the musculoskeletal issues and work factors of the last 12 months or 7 days. It can be modified according to the type of job, or the variables chosen (Crawford, 2007).

The questionnaire used is the Nordic questionnaire modified divided in three sections:

- Section A: Personal Data
- Section B: Problems in the Locomotor System
- Section C: Risk Factors

The variables taken into consideration were (Hidalgo, 2015):

Table 57 Variables in Nordic Questionnaire

Variables	Definition	Dimensions
Gender	Biological genetic variable	-Female -Male
Age	Time a person has lived	None

Work hours	Amount of time (hours) spends per week	Range 0 to 24 hours
MSDs	diseases and conditions of the musculoskeletal system that lead to pain and functional impairment of tendons, muscles, nerves, bones, and other supporting structures of the body.	-Neck -Shoulders -Elbows - Wrists - Upper back - Lower back - Hips - Knees - Feet
Ergonomic measures	Principles for Better Work Performance.	- Yes - No
Physical therapy	Treatment of disease, injury, or deformity by physical methods.	-Yes -No
Degree of physical activity	Includes exercise as well as other activities which involve bodily movement and are done as part of playing, working, active transportation, house chores and recreational activities.	- Active - Sedentary

The principal and important Risk Factors considered for surgeons were (Hidalgo, 2015):

- High number of repetitions
- Lack of breaks
- Sitting for long periods of time.
- Working while standing for long periods of time
- Working in awkward postures
- Perform Spinal Rotations
- Keep the center of gravity away from your body

3.2. EXPERIMENTAL PROCEDURE

3.2.1. Population

The study population was of 8 medical surgeons of “Hospital Teofilo Dávila” at Machala city, who regularly operate in the hospital’s operating rooms.

The medical staff studied varies in age (between 26 to 66), gender (female and male), specialties 8traumatology, resident, internship, general and vascular surgery) and working hours per week (between 4 to 23).

3.2.2. Techniques and Process

The following shows how each field sheet score was obtained according to the angles obtained in the KINOVEA software and the ergonomic system guide.

That is, each part of the body has a score that tells us the guide according to the degrees of flexion or extension of each one. First, in KINOVEA software put the points in the joints and a specific angle is assigned to each part of the surgeon's body, then the guide shows the score of that angle. Finally, the value obtained for each body part is recorded in the field sheet where the overall scores of each group are obtained to end up in the final score as explained in the figures below.

3.2.2.1. RULA Example

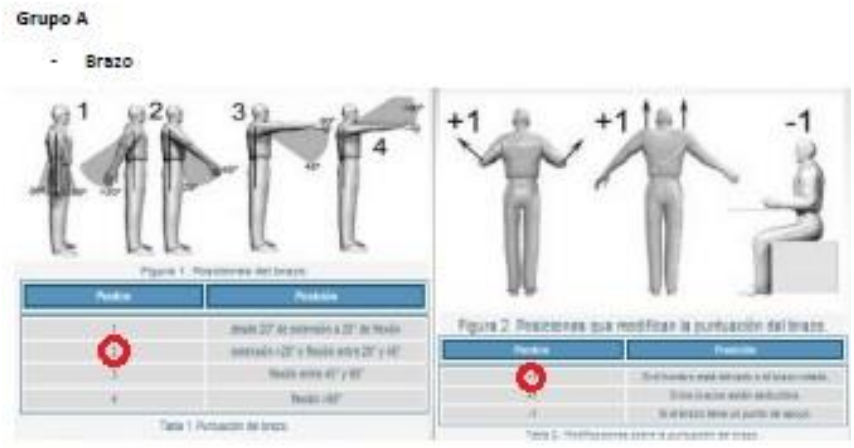


Figure 28 Arm - Group A - RULA Guide

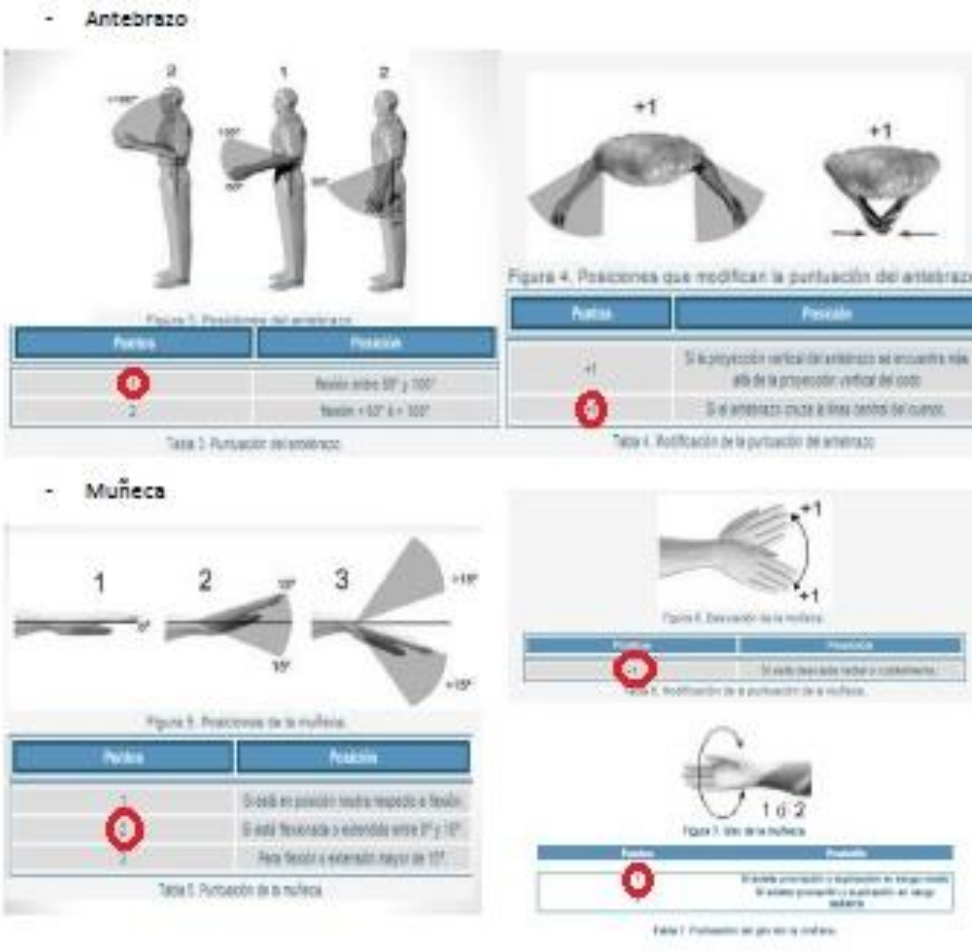


Figure 29 Group A - RULA Guide

Brazo	Antebrazo	Muñeca							
		1		2		3		4	
		Giro Muñeca		Giro Muñeca		Giro Muñeca		Giro muñeca	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	3	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	5	5	5	5
	2	4	4	4	5	5	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Figure 31 Group A - RULA Field Sheet

Figure 30 Angles measure in Kinovea Software (Arm, Neck, Wrist)

- Arms: 2 (Flexion 20° - 45°) + 1 (arm are abducted) = **3**
- Forearms: 1 (flexion 60° - 100°) + 1 (working across the midline of the body) = **2**
- Wrists: 2 (flexion 0 - 15°) + 1 (radial deviation) = **3**
- Twist of wrist: **1** (mid-range of twist)

Total punctuation of Group A= **4**

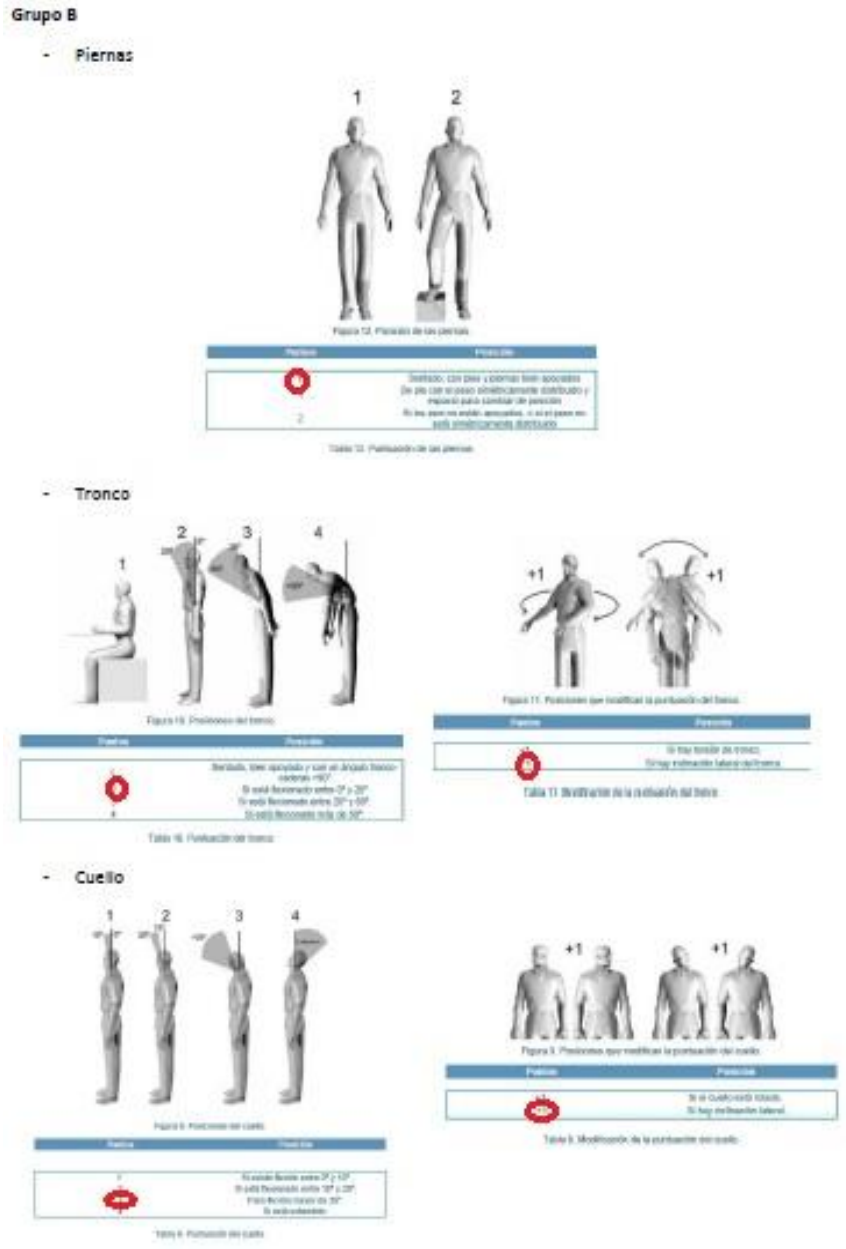


Figure 32 Group B - RULA Guide

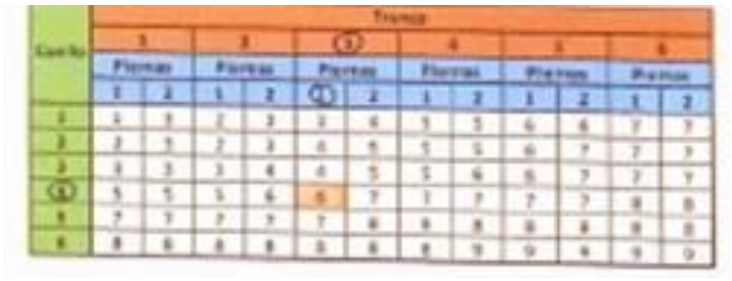


Figure 33 Group B - RULA Field Sheet

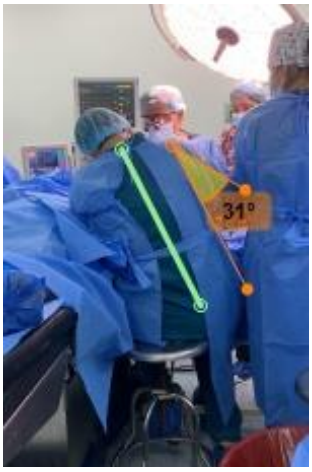


Figure 34 Angles measure in Kinovea software (legs, trunk, neck)

- Legs: **1** (well supported - sitting)
- Trunk: 2 (flexion 0 - 20°) +1 (side-bending) = **3**
- Neck: 3 (flexion >20°) + 1 (side-bending) = **4**

Total punctuation Group B = **6**

Tipo de actividad	Puntuación
Estática (se mantiene más de un minuto seguido)	+1
Repetitiva (se repite más de 4 veces cada minuto)	+1
Ocasional, poco frecuente y de corta duración	0

Tabla 15: Puntuación por tipo de actividad.

Carga o fuerza	Puntuación
Carga menor de 2 Kg. mantenida intermitentemente	0
Carga entre 2 y 10 Kg. mantenida intermitentemente	+1
Carga entre 2 y 10 Kg. estática o repetitiva	+2
Carga superior a 10 Kg mantenida intermitentemente	+2
Carga superior a 10 Kg estática o repetitiva	+3
Se producen golpes o fuerzas bruscas o repentinas	+3

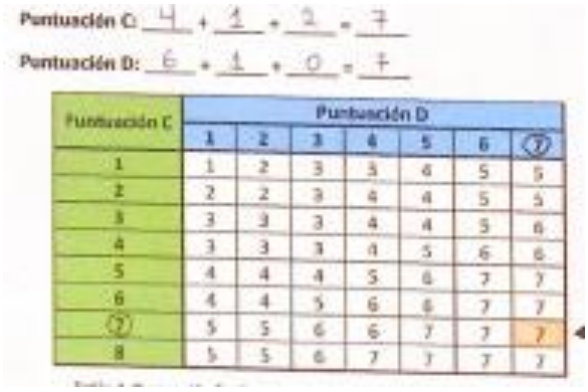


Figure 35 Final punctuation - RULA Field Sheet

Figure 36 Type of activity and force or load - RULA Guide

- Punctuation C: 4 (group A) + 1 (type of activity: static) + 2 (2 - 10 Kg static load) = **7**
- Punctuation D: 6 (group B) + 1 (type of activity: static) = **7**

Final punctuation = **7**

3.2.2.2. REBA Example

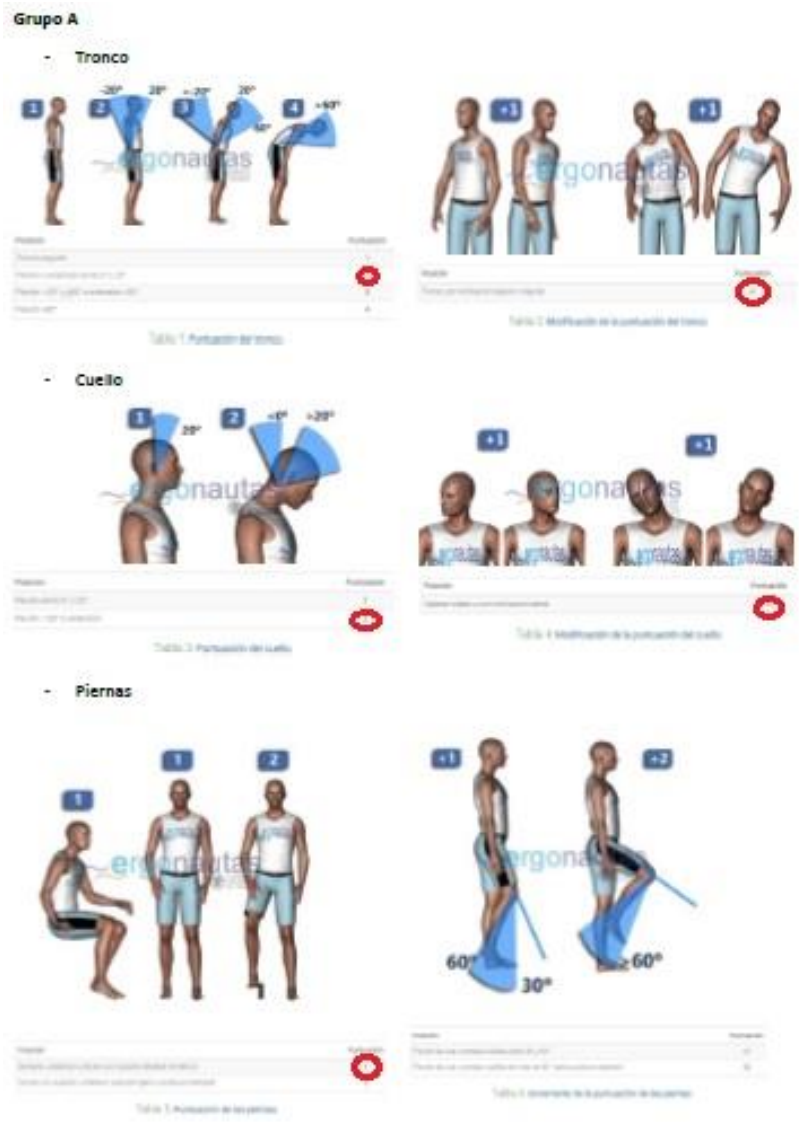


Figure 37 Group A - REBA Guide

Tronco	Cuello 1				Cuello 2				Cuello 3			
	Piernas 1	2	3	4	Piernas 1	2	3	4	Piernas 1	2	3	4
1	1	2	3	4	1	2	3	4	3	3	5	6
2	2	3	4	5	3	4	5	6	4	5	6	7
3	2	4	5	6	4	5	6	7	5	6	7	8
4	3	5	6	7	5	6	7	8	6	7	8	9
5	4	6	7	8	6	7	8	9	7	8	9	9

Figure 39 Group A - REBA Field Sheet

- Trunk: 2 (flexion 0 -20°) + 1 (side flexed) = **3**

Figure 38 Angles measures in Kinovea software (trunk, neck, legs)

- Neck: 2 (flexion >20°) + 1 (side flexed) = **3**
- Legs: **1** (bilateral weight bearing)

Total punctuation Group A = **5**

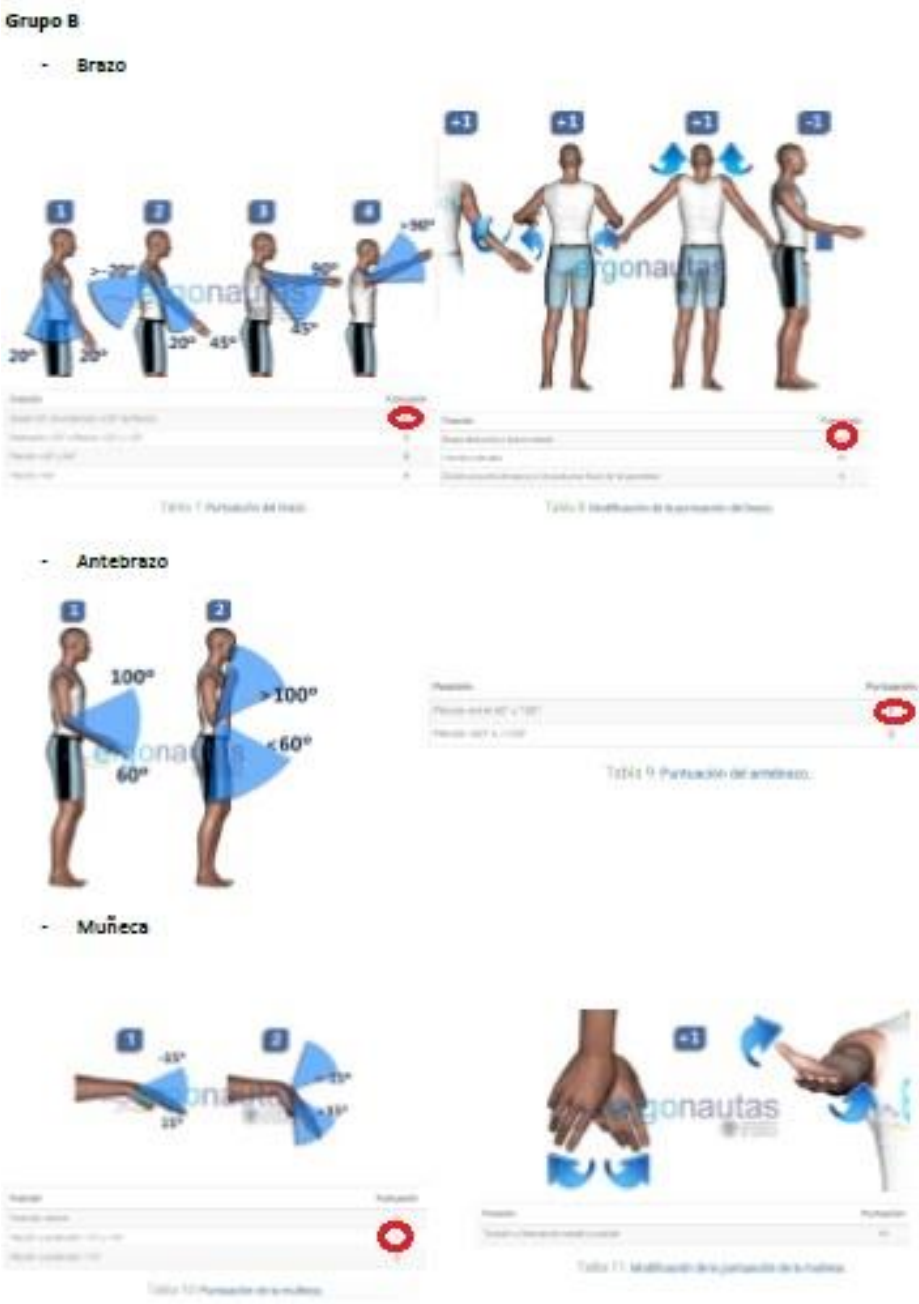


Figure 40 Group B - REBA Guide

Brazo	Antebrazo					
	1			2		
	Muñeca			Muñeca		
	1	2	3	1	2	3
1	1	2	2	1	2	3
2	1	2	3	2	9	4
3	3	4	5	4	5	5
4	4	5	5	5	6	7
5	6	7	8	7	8	8
6	7	8	8	8	9	9

Figure 42 Group B - REBA Field Sheet

Figure 41 Angles measure in Kinovea software (forearm, arm, wrist)

- Arms: 1 (flexion 0 -20°) + 1 (arm abducted) = **2**
- Forearms: **1** (flexion 60 ° - 100°)
- Wrists: **1** (flexion 0 - 15°)

Total punctuation Group B = **1**

Carga o fuerza	Puntuación
Carga o fuerza menor de 5 Kg	0
Carga o fuerza entre 5 y 10 Kg	+1
Carga o fuerza mayor de 10 Kg	+2

Carga o fuerza	Puntuación
Existen fuerzas o cargas aplicadas bruscamente	+1

Calidad de agarre	Descripción	Puntuación
Bueno	El agarre es bueno y la fuerza de agarre de rango medio	0
Regular	El agarre es aceptable pero no ideal o el agarre es aceptable utilizando otras partes del cuerpo	+1
Malo	El agarre es posible pero no aceptable	+2
Inaceptable	El agarre es torpe e inseguro, no es posible el agarre manual o el agarre es inaceptable utilizando otras partes del cuerpo	+3

Figure 43 Load or force - REBA Guide

Puntuación A: 5 + 0 + ____ + ____ = 5

Puntuación B: 1 + 0 + ____ + ____ = 1

Figure 44 Puntuaction A and B - REBA Field Sheet

Puntuación A	Puntuación B											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Figure 45 Punctuation C - REBA Field Sheet

- Punctuation A: 5 (Group A) + 0 (load < 5Kg) = **5**
- Punctuation B: 1 (group B) + 0 (grip quality: good) = **1**

Punctuation C = **4**

Tipo de actividad muscular	Puntuación
Una o más partes del cuerpo permanecen estáticas, por ejemplo sostenidas durante más de 1 minuto	+1
Se producen movimientos repetidos, por ejemplo repetidos más de 4 veces por minuto (excluyendo caminar)	+1
Se producen cambios de postura importantes o se adoptan posturas inestables	+1

Figure 46 Type of muscular activity - REBA guide

Puntuación Final: 4 + 3 = 7

Figure 47 Final punctuation

Final punctuation: 4 (punctuation C) + 3 (muscle activity: static, repeated and rapid changes postures) = **7**

Level Action: **2**: medium risk - necessary action.

-9

3.2.2.3. OCRA Example

Figure 48 Recovery Time - OCRA guide

Figure 49 Recovery Time - Ocra Field Sheet

Figure 50 Frequency - OCRA guide

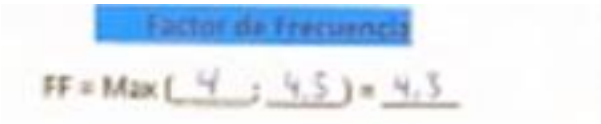


Figure 51Frequency - OCRA Field Sheet

Figure 52 Force - OCRA guide

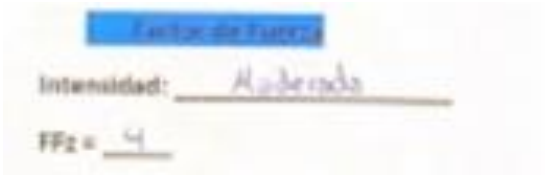


Figure 53 Force - OCRA Field Sheet

Figure 54 Posture of different body part - OCRA Guide

$$FP = Max (PHo ; PCo ; PMu ; PMa) + PEs$$

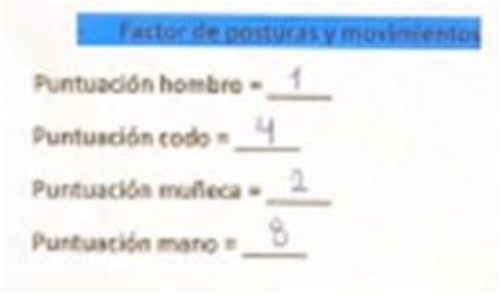


Figure 55 Posture of different body part - OCRA Field Sheet

Figure 56 Additional factors - OCRA guide

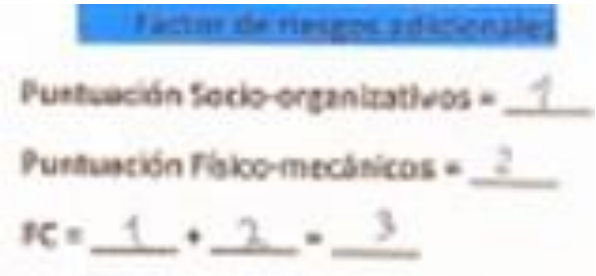


Figure 57 Additional factors - OCRA Field Sheet

Figure 58 Duration multiplier - OCRA guide

Figure 59 Duration multiplier - OCRA Field Sheet

Figure 60 Check List - OCRA Guide

Figure 61 Check List - OCRA Field Sheet

Final Punctuation = **20,8**

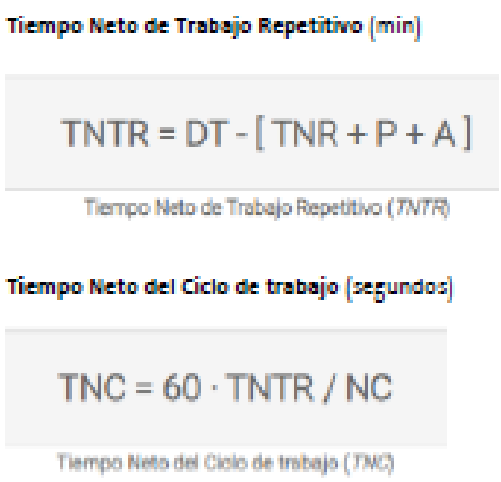


Figure 62 Net total cycle time - OCRA Guide

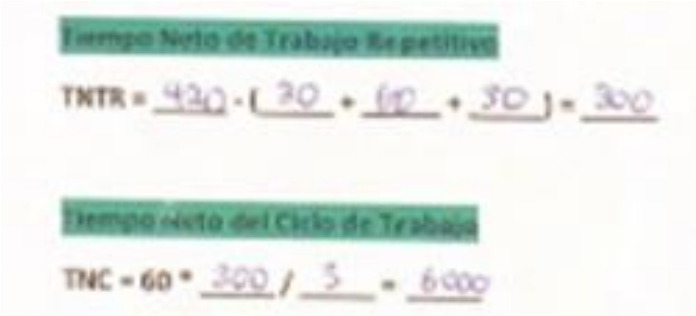
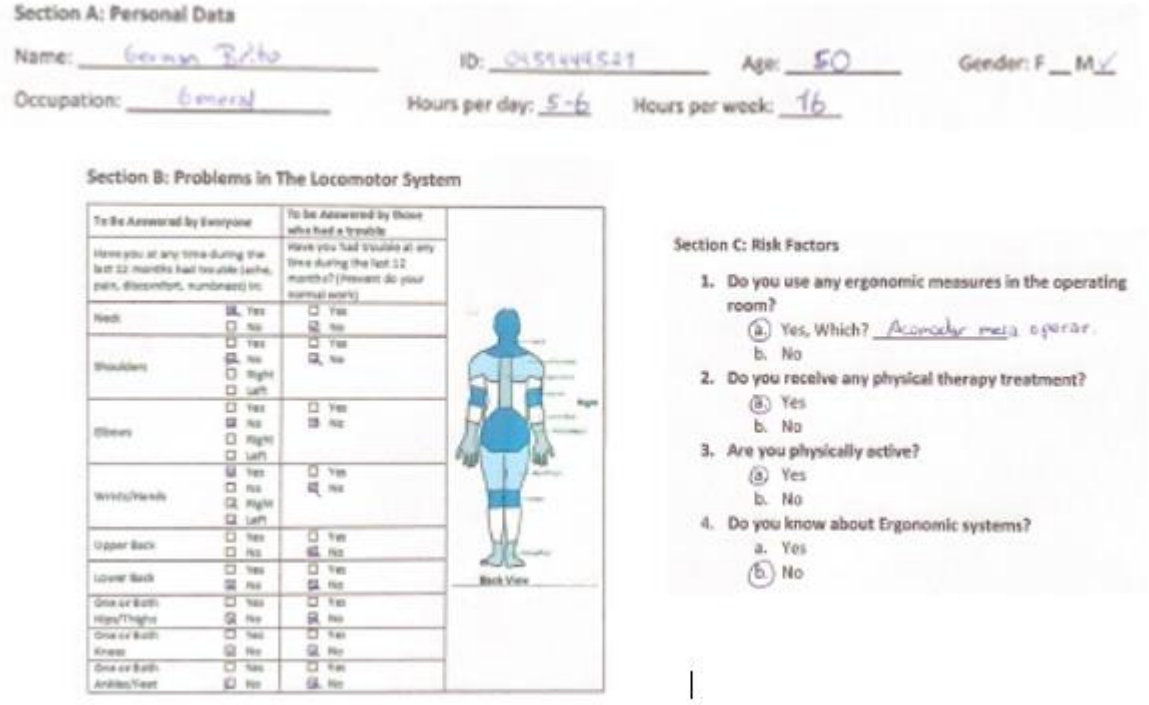


Figure 63 Net totalcycle time - OCRA Field Sheet

Level Action: **>9** = High - recommended job upgrading and medical supervision.

3.2.2.4. Nordic Questionnaire Example

Figure 64 is the Nordic questionnaire example that was made to surgeons to know the general data such as name, ID, age, gender, occupation, and working hours per week. Also, there are two more sections to find out about the musculoskeletal disorders that suffer, and the knowledge of ergonomic measures.



Section A: Personal Data

Name: [illegible] ID: [illegible] Age: 50 Gender: F__ M✓

Occupation: General Hours per day: 5-6 Hours per week: 16

Section B: Problems in The Locomotor System

To Be Answered by Everyone		To be Answered by those who had a trouble
Have you at any time during the last 12 months had trouble (ache, pain, discomfort, numbness) in:		Have you had trouble at any time during the last 12 months? (Prevent do your normal work)
Neck	☒ Yes ☐ No	☐ Yes ☒ No
Shoulders	☐ Yes ☒ No ☐ Right ☐ Left	☐ Yes ☒ No
Elbows	☐ Yes ☒ No ☐ Right ☐ Left	☐ Yes ☒ No
Wrists/Hands	☒ Yes ☐ No ☒ Right ☐ Left	☐ Yes ☒ No
Upper Back	☐ Yes ☐ No	☐ Yes ☒ No
Lower Back	☐ Yes ☒ No	☐ Yes ☒ No
One or Both Hips/Thighs	☐ Yes ☒ No	☐ Yes ☒ No
One or Both Knees	☐ Yes ☒ No	☐ Yes ☒ No
One or Both Ankles/Feet	☐ Yes ☐ No	☐ Yes ☒ No

Back View

Section C: Risk Factors

1. Do you use any ergonomic measures in the operating room?
   - (a) Yes, Which? Acondicionador
   - b. No
2. Do you receive any physical therapy treatment?
   - (a) Yes
   - b. No
3. Are you physically active?
   - (a) Yes
   - b. No
4. Do you know about Ergonomic systems?
   - a. Yes
   - (b) No

Figure 64 Nordic questionnaire.

3.2.3. Work Methodology

The work methodology is divided in four phases, in the first phase the location of the hospital, the surgeons and the surgery types are studied. Once the locations are identified, the next phase is the record of data, photos and video were used for this phase. The third phase is the evaluation of the data obtained using Kinovea software, and finally for the fourth phase, the information obtained with the field sheets was analyzed to obtain the results.

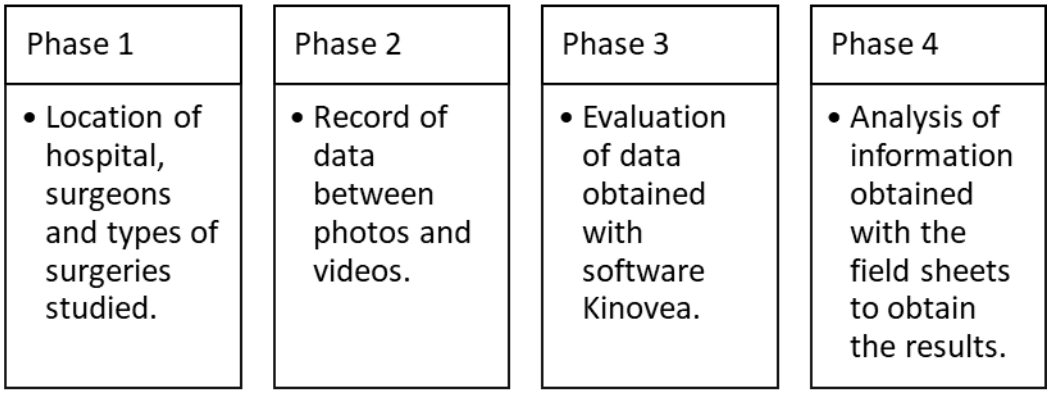


Figure 65 Work methodology.

3.2.4. Application Procedure

3.2.4.1. RULA

The process for collecting the risk level using RULA is shown in Figure LXV, first the score of the arm, forearm, wrist and twist of the wrist are collected to form the Score Group “A”, this score is added with the score from forces or loads and the type of activity, obtaining the score “C”. In the same way, from the Neck, Trunk and Legs, the Score Group “B” is collected, to this score are added the score from forces or loads and the type of activity, resulting in Score “D”. With the adding of Score “C” and “D”, the final score is calculated obtaining the risk level.

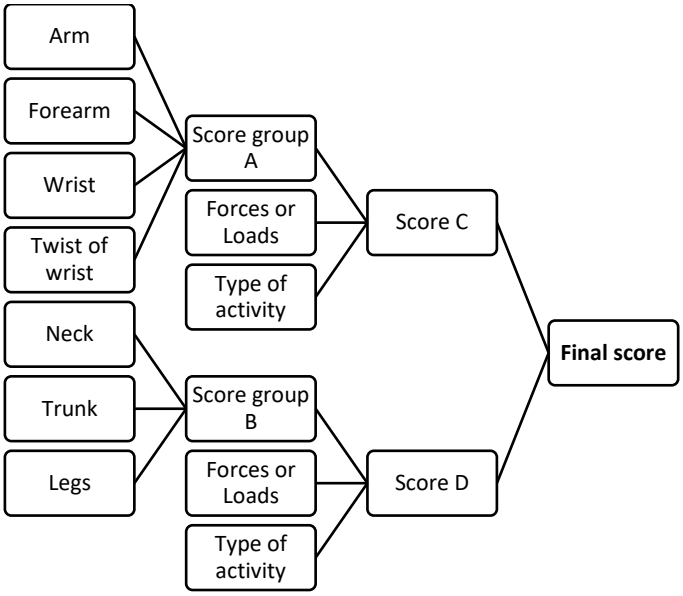


Figure 66 RULA process. Own wlaboration from (Mas & Antonio, 2015e)

3.2.4.2. REBA

The process for collecting the risk level using REBA is shown in Figure LXVI, first the score of the neck, trunk and legs are collected to form the Score Group "A", this score is added with the score from forces or loads, obtaining the score "A". In the same way, from the arm, forearm, and wrist, the Score Group "B" is collected, to this score is added the score from grip quality, resulting in Score "B". Adding the score "A" to the score "B", the result is score "C", and with this score is added the type of activity score to calculate the final score obtaining the risk level.

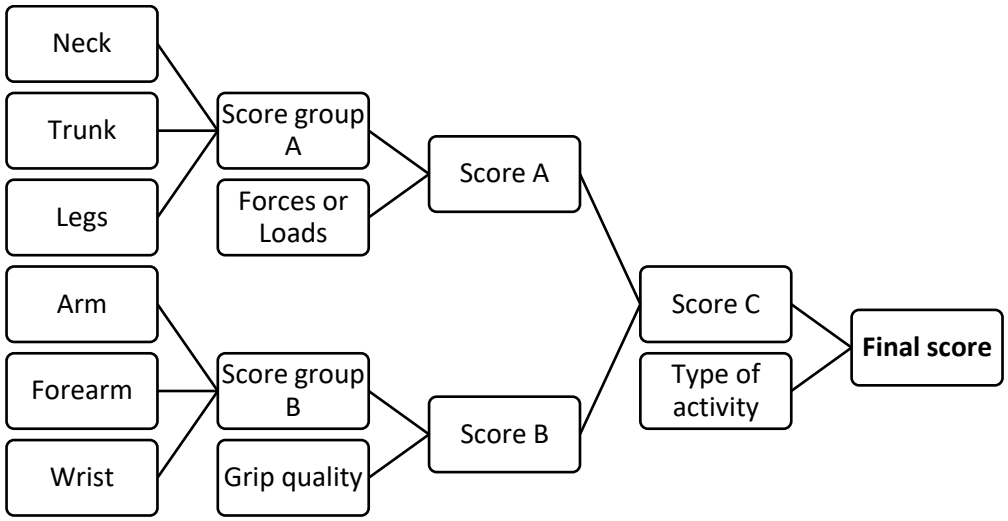


Figure 67 REBA process. Own elaboration from (Mas & Antonio, 2015d)

3.2.4.3. OCRA

The process for collecting the risk level using OCRA is shown in Figure LXVII, since this method uses equations and scoring tables to evaluate the risk factor, the process for obtaining the final score is different from Figure LXV and LXVI. First the ICKL is determined using the sum from five factors (recovery time, frequency, force, posture and some additional) and this score is multiplied by the duration multiplier, as shown in equation ….. In the other hand, the TNTR must be calculated using the duration of the shift, before using this value, first the non-repetitive work, the breaks and the lunch breaks must be added, to finally be subtracted from the duration of shift, as shown in equation …… Finally, the TCN is obtained by multiplying the TNTR score by sixty and dividing this value to the number of cycles as shown in equation …. This is how the risk level from OCRA is obtained.

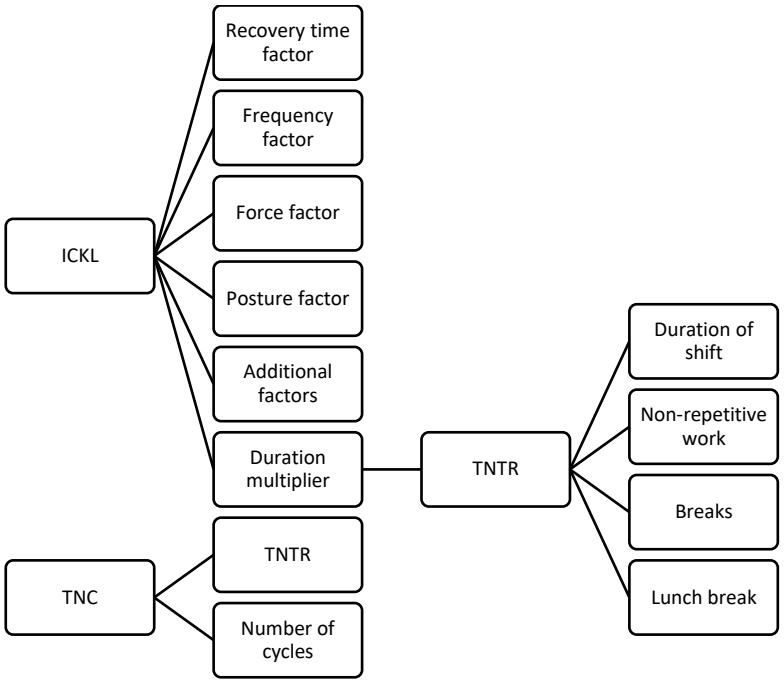


Figure 68 OCRA Checklist Data. Own elaboration from (Colombini et al., 2013)

CHAPTER 4

4.1. RESULTS

This investigation was realized to demonstrate the ergonomic risks in 8 surgeons of different specialties at “Hospital Teofilo Davila” in Machala. It was used 3 ergonomic methods: RULA, REBA and OCRA through of photos and videos taken at the operating rooms for 2 months.

A total of 10 surgeries were analyzed with 2 surgeons in each one (on-call surgeons repeated themselves in the surgeries). The total population is of 20 participants.

4.1.1. Nordic questionnaire

4.1.1.1. Gender

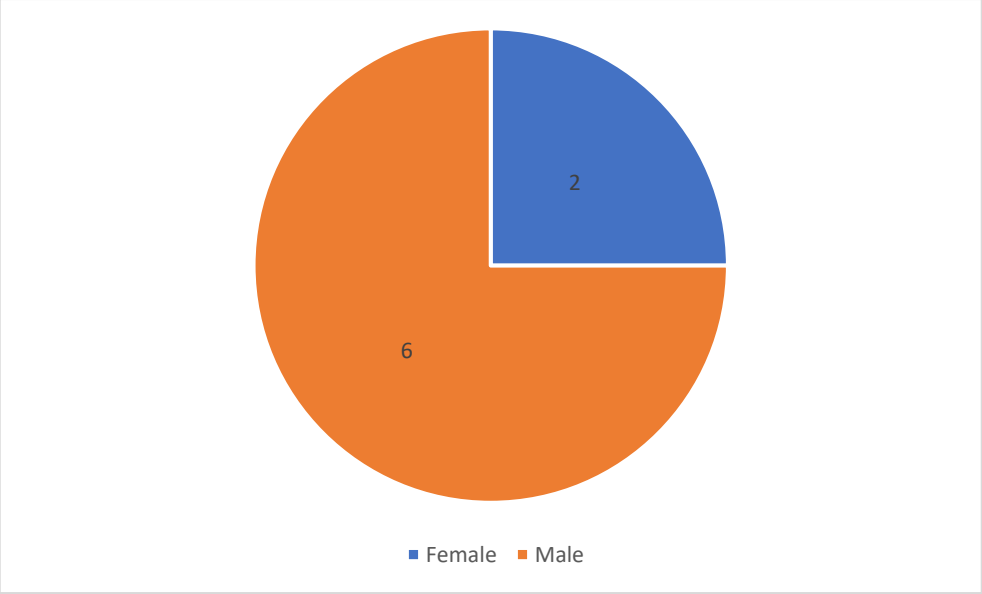


Figure 69 Gender frequency of the population.

Regarding gender, there was a greater number of men of the 8 surgeons of the population. The 75% was men and 25% women.

4.1.1.2. Age

Table 58 Age frequency of the population

Participant	Age
1	66
2	56
3	50
4	26
5	39
6	34
7	43
8	62

There is a range of ages from 26 to 66 years with an average age of 47 years. The 50% above average and the other 50% below average.

4.1.1.3. Specialties

Table 59 Specialities of surgeons

Specialties	Number of surgeons
Traumatology	2
General Surgery	2
Resident	1
Vascular surgery	2
Internship	1

The work was performed with surgeons from 5 different specialties. However, most of the surgeries performed at the hospital are trauma and laparoscopic.

4.1.1.4. Surgeries per week

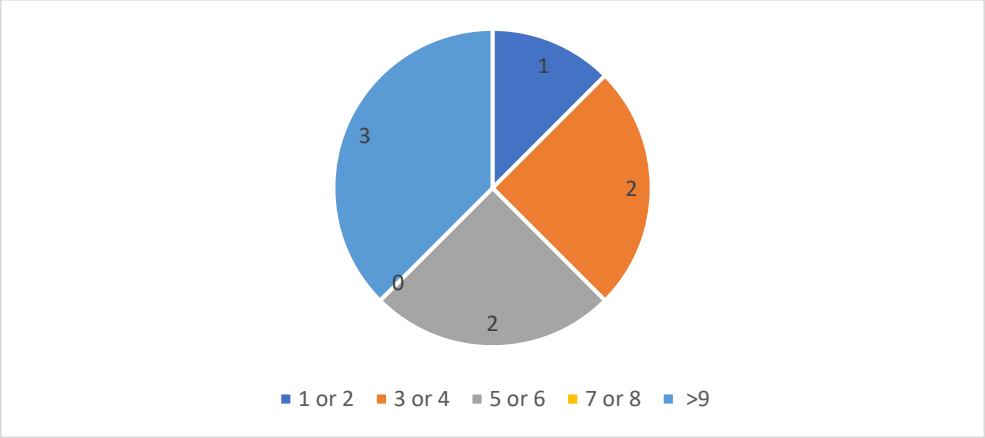


Figure 70 Surgeries per week frequency of the population

The surgeries per week that have the doctors are constantly changing due to the emergency interventions and type of surgery. However, between 3 or 4 laparoscopic surgeries are programed 3 days per week, so the 3 surgeons have more than 9 surgeries.

4.1.1.5. Hours per week

Table 60 Hour's frequency of the population

Participant	Hours
1	13
2	23
3	16
4	13
5	13
6	9
7	4
8	4

The hours per week is an important factor that allows to differentiate as the number of surgeries per week because some surgeries such as trauma are longer, and the laparoscopic surgeries are the shortest. Participant 2 is the doctor with more hours per week belongs to the specialty of vascular surgery and has 6 surgeries per week.

4.1.1.6. Ergonomic measures in the operating room

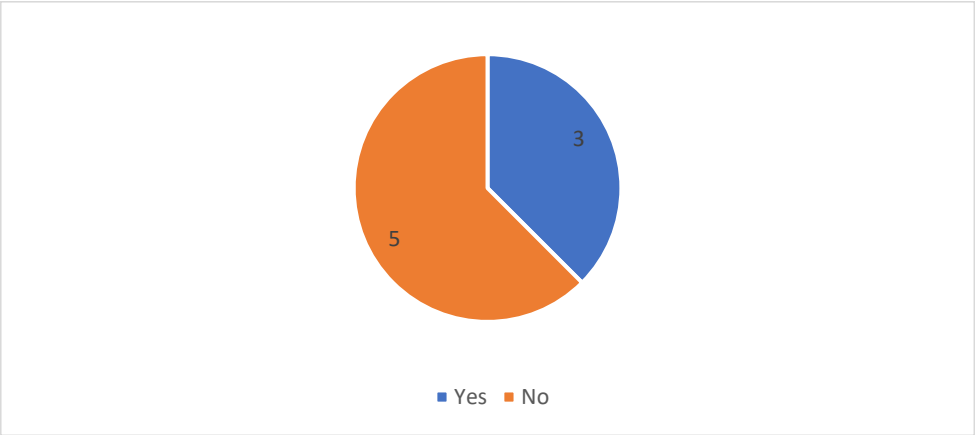


Figure 71 Ergonomic measures frequency of the population

Only 3 doctors use any ergonomic measure such as accommodate the hospital gurney or biomedical devices. The 62.5% of doctors don't used or don't know about mechanisms to reduce injuries in the operating room and the 37.5% try to use any measure.

4.1.1.7. Physical Therapy

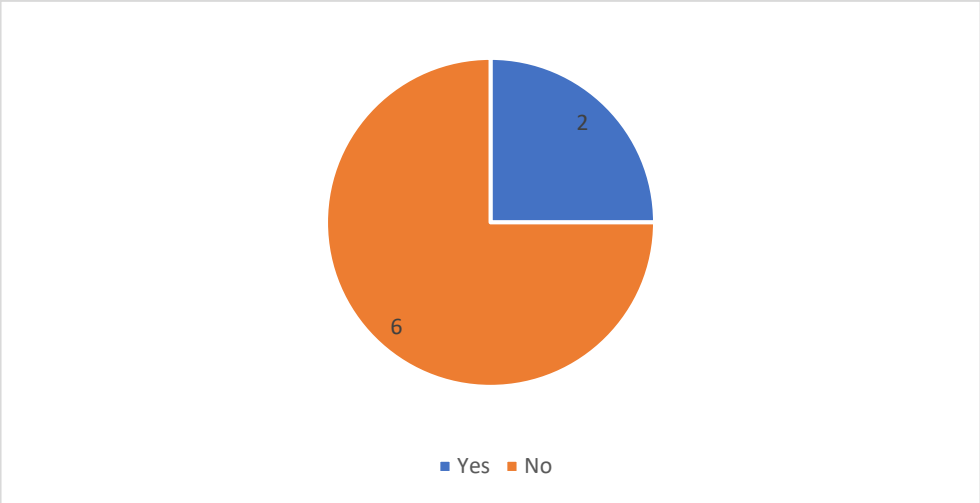


Figure 72 Physical therapy frequency of the population

The 75% of the surgeons don't receive any treatment for the injuries that feel and the 25% often go to physiotherapy centers. The two doctor that receive a treatment also are physically active.

4.1.1.8. Physically active

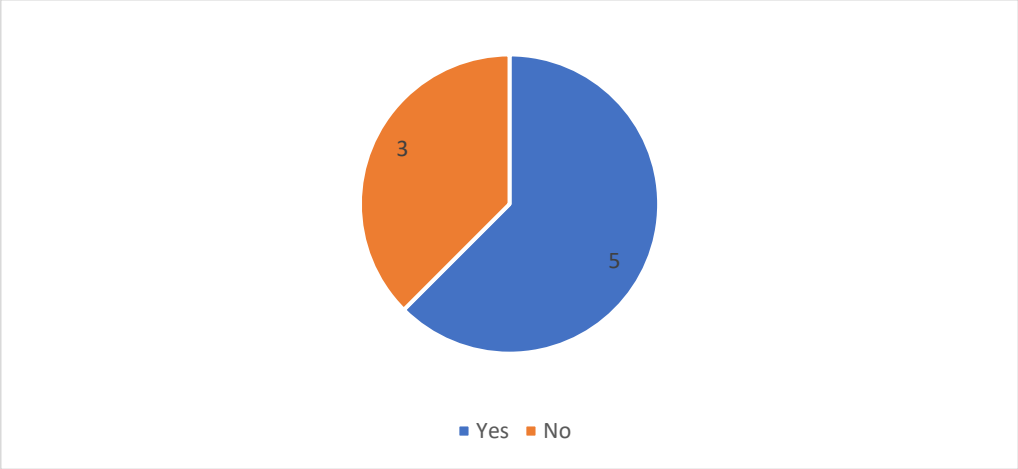


Figure 73 Physically active frequency of the population

The 62.5% of doctors realize any physical activity within their daily routine and the 37.5% some doctors are sedentary, and others rarely practice any sport on a recreational basis.

4.1.1.9. Problems in Locomotor System

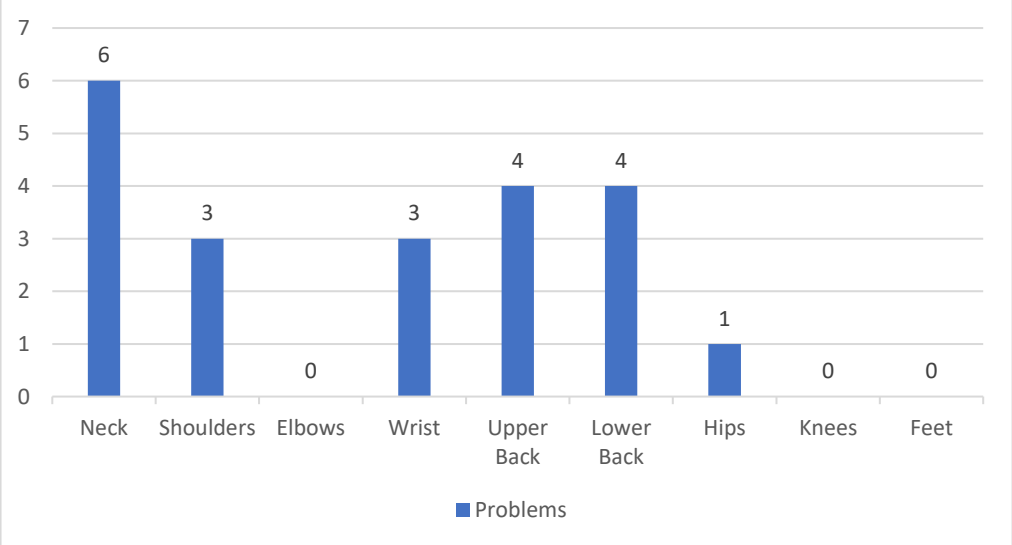


Figure 74 Problems frequency of the population

The sites where the surgeons perceive more pain or discomfort are neck, upper back, and lower back. This is due to the postures now of the surgical intervention whether standing or seated.

4.1.1.10. Frequency of MSDs.

Table 61 Relation between MSDs and variables

Variable	Dimension	Frequency	Percentage
Gender	Female	1	50%
	Male	6	100%
Age	>47 years	4	100%
	<47 years	3	75%
Hours per week	< 12 hours	4	80%
	> 12 hours	3	100%

4.1.2. RULA method analysis

Each participant of the population was evaluated during a surgical intervention with the RULA field sheet and Kinovea Software, which resulted in one action level of this method detailed following:

Table 62 Risk levels of RULA method

Level	Action
1	Posture is acceptable if it is not maintained or repeated for long periods.
2	Further investigation is needed, and changes may be required.
3	Investigation and changes are required soon.
4	Investigation and changes are required immediately.

4.1.2.1. Risk level

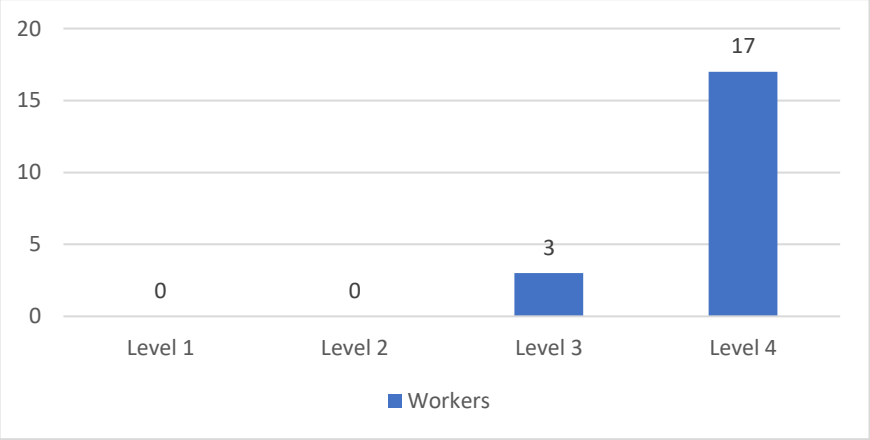


Figure 75 RULA risk levels

The 85% of the population resulted in the level 4 that is the highest risk level in the scale and the 15% in the level 3.

4.1.2.2. Postures with the highest ergonomic risk

Table 63 Postures with the highest RULA ergonomic risk

Body parts							Number of doctors	Frequency
Arm	Forearm	Wrist	Twist of wrist	Trunk	Legs	Neck		
3	2	3	1	3	1	4	3	3 times
3	2	3	1	2	1	4	1	1 time
2	2	3	1	3	1	4	2	2 times
2	2	2	1	2	1	3	1	1 time
3	2	2	1	3	1	2	1	1 time
3	2	3	1	3	1	2	2	3 times
2	2	3	1	3	1	3	1	1 time
2	2	3	1	3	1	2	1	1 time
3	2	3	1	4	1	4	4	4 times
4	2	3	1	4	1	4	1	1 time
3	2	3	1	4	1	3	1	1 time
3	2	3	1	3	1	3	1	1 time

The results also show that the most affected parts of the body were neck, trunk, and wrists.

4.1.2.3. Relation Gender-RULA

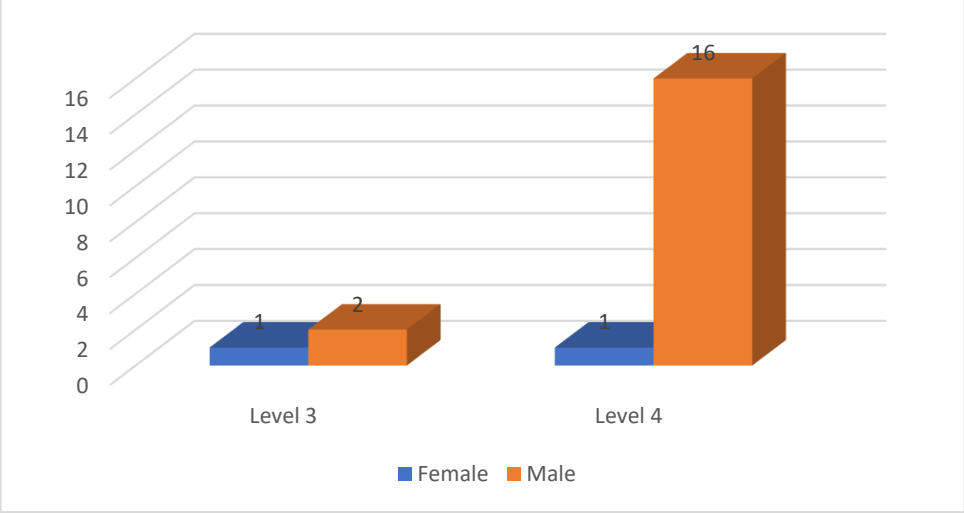


Figure 76 Relation between risk level and gender

The figure show that the majority of the male population is at the highest risk level. There is a one woman in level 3 and 1 in level 4.

4.1.2.4. Relation Age-RULA

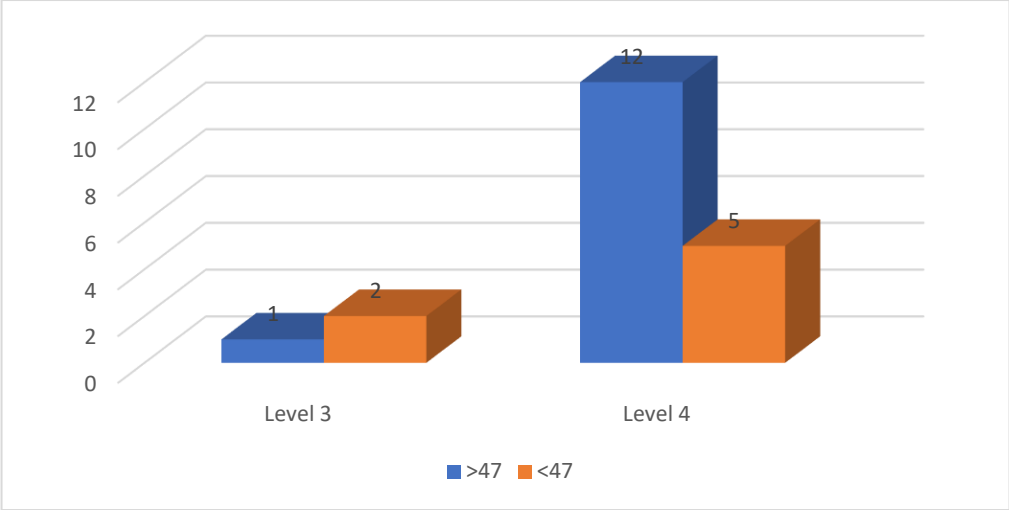


Figure 77 Relation between risk level and age

The population that are over 47 years old are in the highest risk level, however most of the population under 47 years also is in the level 4 in smaller quantities.

4.1.2.5. Relation hours per week RULA

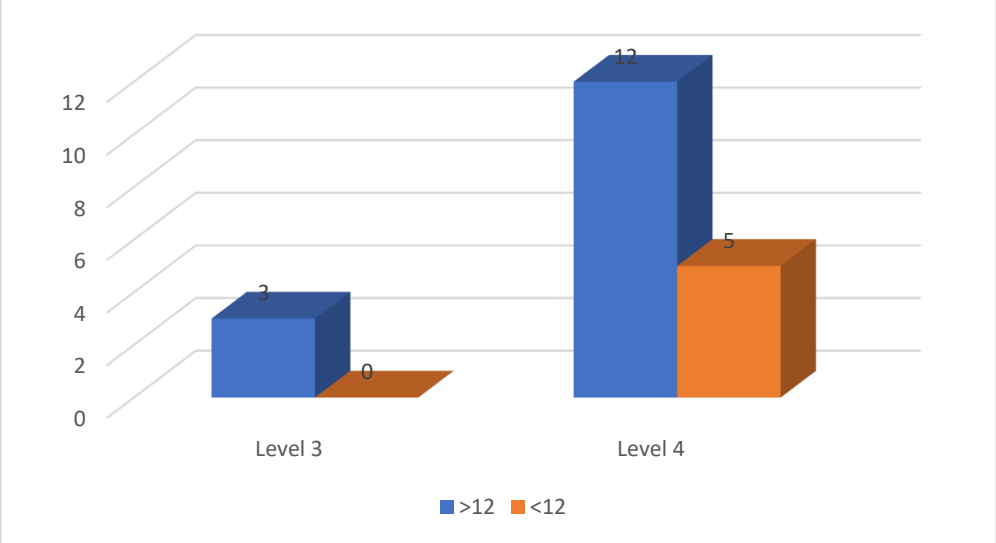


Figure 78 Relation between risk level and hours per week

The figure show that most of the population that is in level 4 is whom work more than 12 hours per week.

4.1.3. REBA method analysis

Each participant of the population was evaluated during a surgical intervention with the RULA field sheet and Kinovea Software, which resulted in one action level of this method detailed following:

Table 64 Risk level of REBA method

Level	Risk	Action
0	Negligible	None necessary
1	Low	May be necessary
2	Medium	Necessary
3	High	Necessary soon
4	Very high	Necessary NOW

4.1.3.1. Risk level

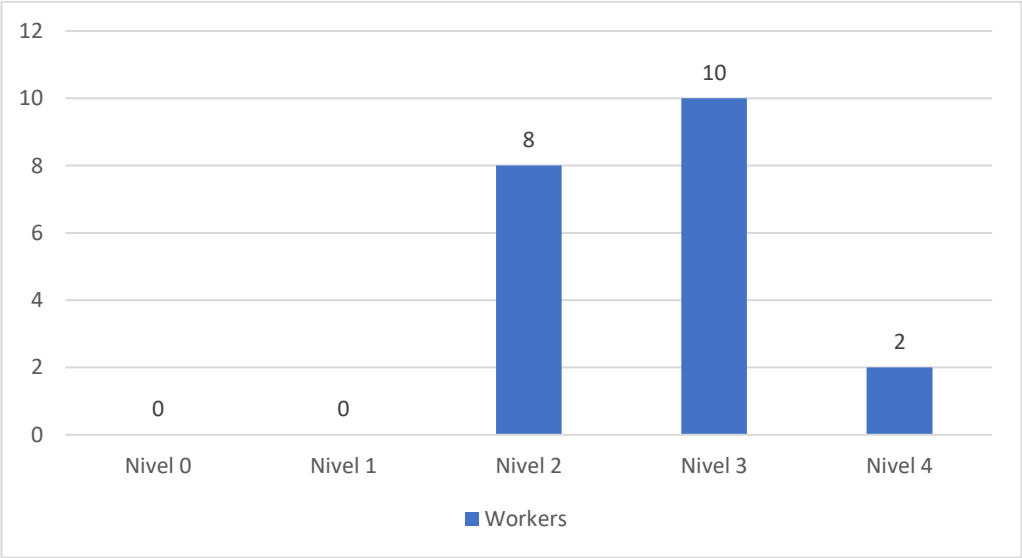


Figure 79 REBA Risk Level

The 50% of the population resulted in the level 3, the 40% in the level 2 and the 10% in the level 4 that is the highest risk level in the scale.

4.1.3.2. Postures with the highest ergonomic risk

Table 65 Postures with the highest REBA ergonomic risk

Body parts						Number of doctors	Frequency
Trunk	Neck	Legs	Arm	Forearm	Wrist		
3	3	1	3	1	2	3	3 times
3	2	1	3	1	2	1	1 time
3	2	1	4	1	2	1	1 time
3	3	1	2	1	2	1	1 time
4	3	1	2	1	2	1	1 time
4	3	1	3	1	2	3	4 times

The results also show that the most affected parts of the body were trunk and neck.

4.1.3.3. Relation Gender - REBA

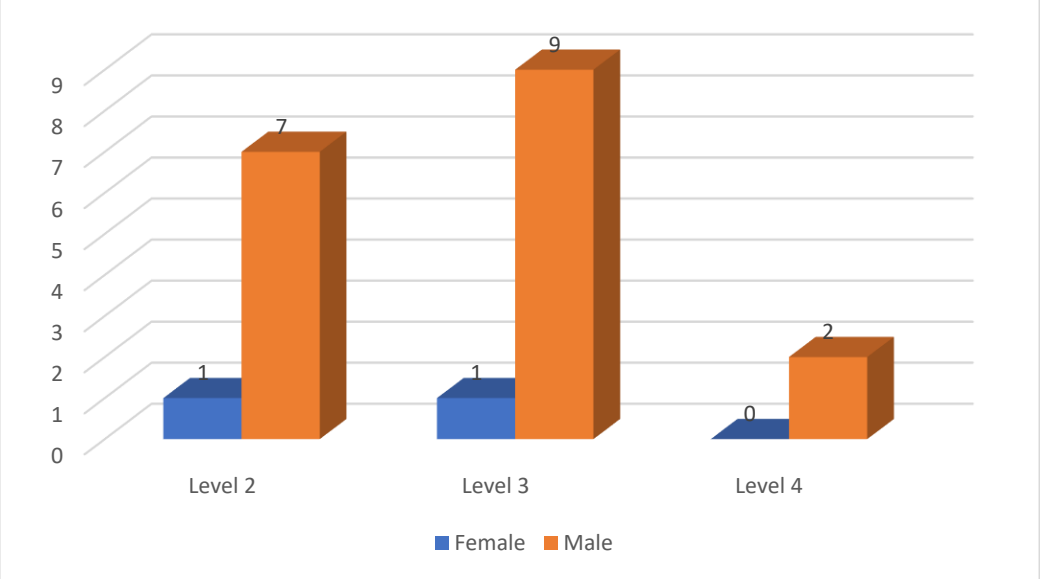


Figure 80 Relation between REBA level and Gender

Most of the male population is in the level 3 and 2, only to participants are in the highest risk level.

4.1.3.4. Relation Age-REBA

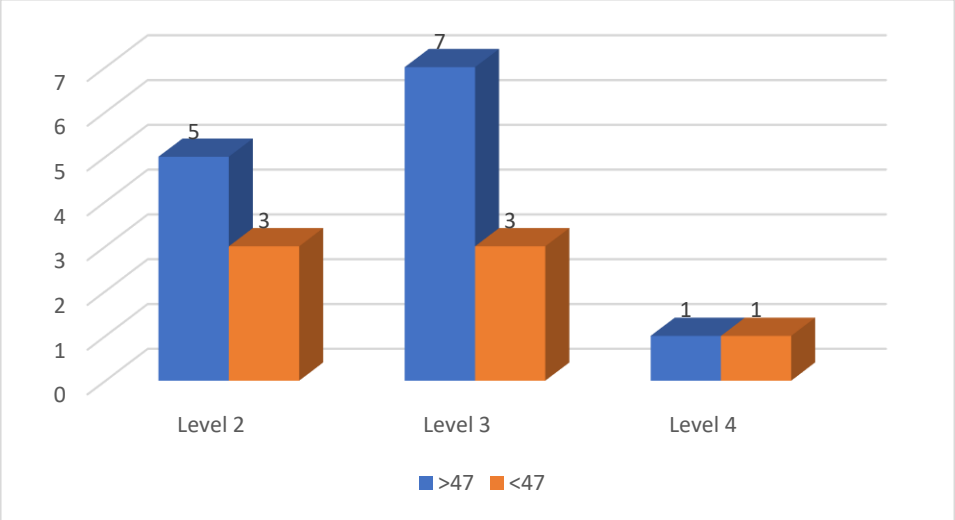


Figure 81 Relation between REBA levels and Age

The 53.8% of the population that is over de 47 years are in the level 3 and the 38.5% are in level 2. One 42.8% of the population under de 47 years are in the level 3 and the other is in the level 2.

4.1.3.5. Relation Hours per week-REBA

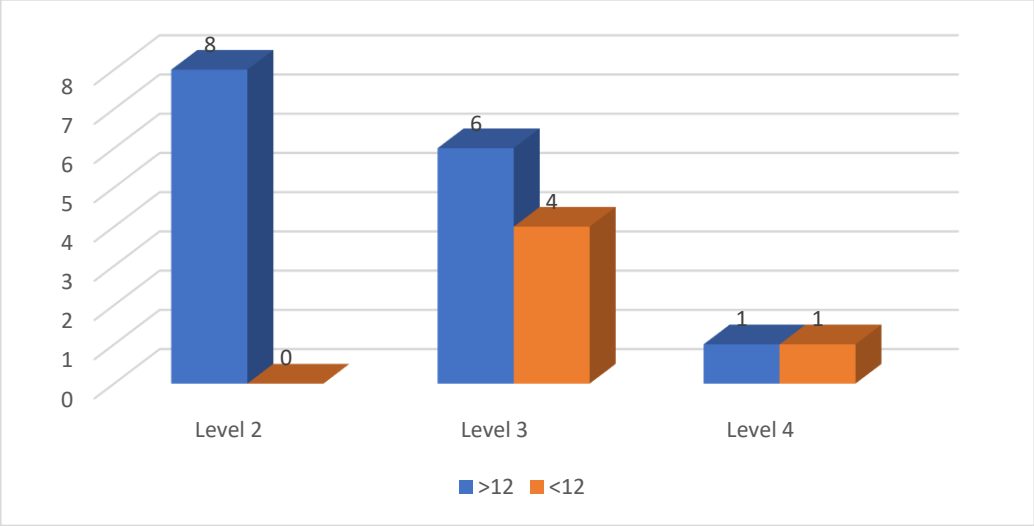


Figure 82 Relation between REBA lelvels and Hours per week

More than the 50% of the population that work more than 12 hours per week are in level 2, however, the 40% of the same population is in level 3. The 80% of the population that work less of 12 hours are in the level 3.

4.1.4. OCRA method analysis

Each participant of the population was evaluated during a surgical intervention with the OCRA field sheet, which resulted in one action level of this method detailed following:

Table 66 OCRA action levels

ICKL	Risk Level	Action
≤ 5	Optimal	Not required
5.1 - 7.5	Acceptable	Not required
7.6 - 11	Borderline or very low	A new analysis or improvement of the position is recommended
11.1 - 14	Low	Recommended job upgrading, medical supervision and training
14.1 - 22.5	Medium	Recommended job upgrading, medical supervision and training
>22.5	High	Recommended job upgrading, medical supervision and training

4.1.4.1. Risk level

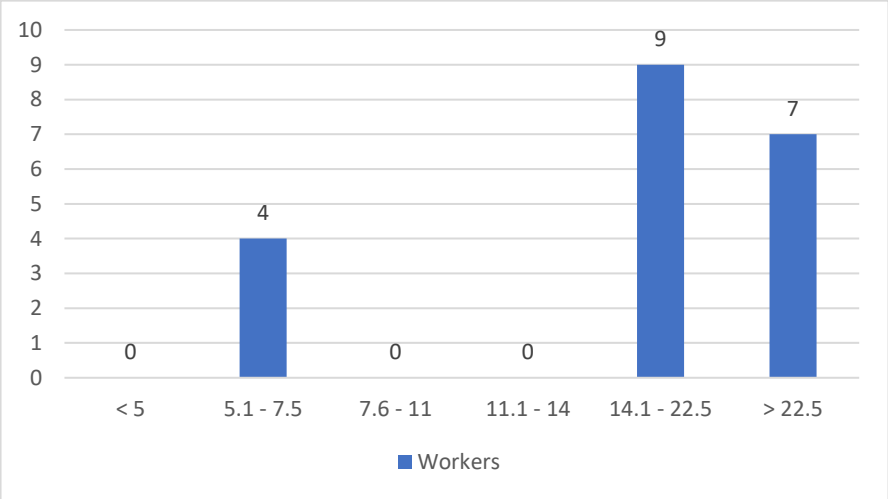


Figure 83 OCRA Level

The 45% of the participant are in the level between 14.1 - 22.5 of the OCRA scale, the 35% are in the >22.5 scale and the 20% remaining is in the scale between 5.1 to 7.5.

4.1.4.2. Postures with the highest ergonomic risk

Table 67 Postures with the highest OCRA ergonomic risk

OCRA Checklist index						Number of doctors	Frequency
FR	FF	FFz	FP	FC	MD		
0	6	4	11	3	1	2	2
0	4.5	6	11	3	0.95	2	2
2	4.5	4	11	3	0.85	1	1
2	4.5	4	11	3	0.95	1	1
0	4.5	4	11	3	0.95	2	3
0	4.5	4	11	3	0.85	1	1
0	8	24	11	3	0.85	2	2
0	4.5	4	11	3	0.925	2	4

The results also show that the factors that more affect in the surgeons are frequency factor about the dynamic or static technical actions and posture factor that punctuates the movements of different parts of the body.

4.1.4.3. Relation Gender - OCRA

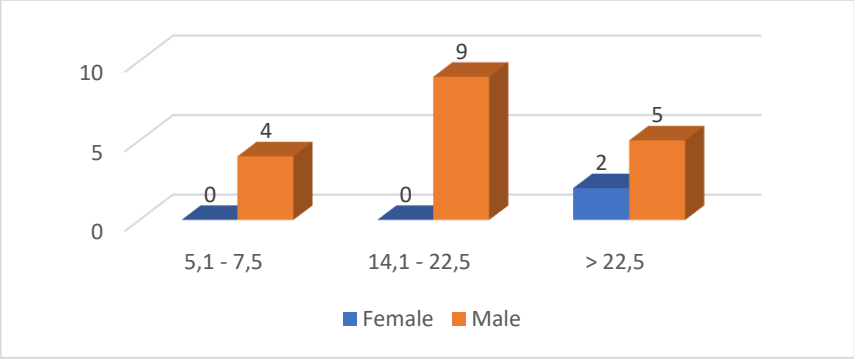


Figure 84 Relation between OCRA index and Gender

Most of the male population is in the 14.1-22.5 OCRA index, and all the female population is in the highest OCRA index.

4.1.4.4. Relation Age - OCRA

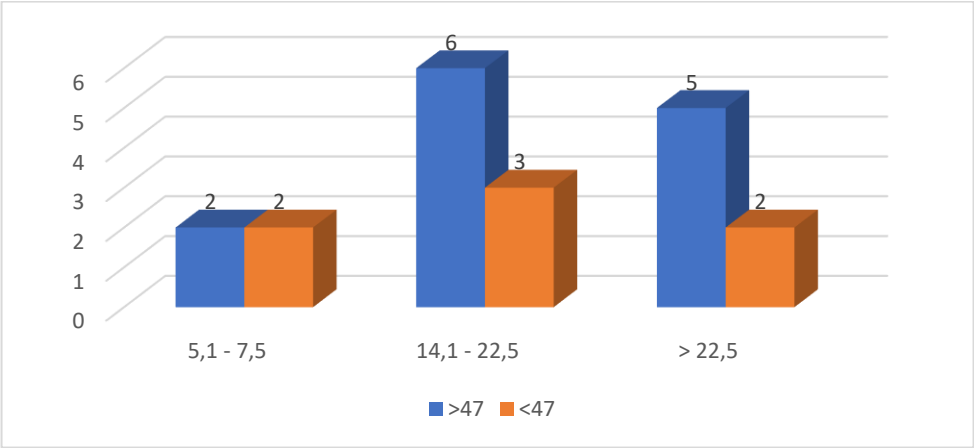


Figure 85 Relation between OCRA index and Age

The 46.2% of participant over the 47 years are in the 14.1-22.5 OCRA index, the 38.5% are in the >22.5 index and 15.4% are in the 5.1-7.5 index. The participants under the 47 years are evenly distributed in the 3 levels described above.

4.1.4.5. Relation Hours per week - OCRA

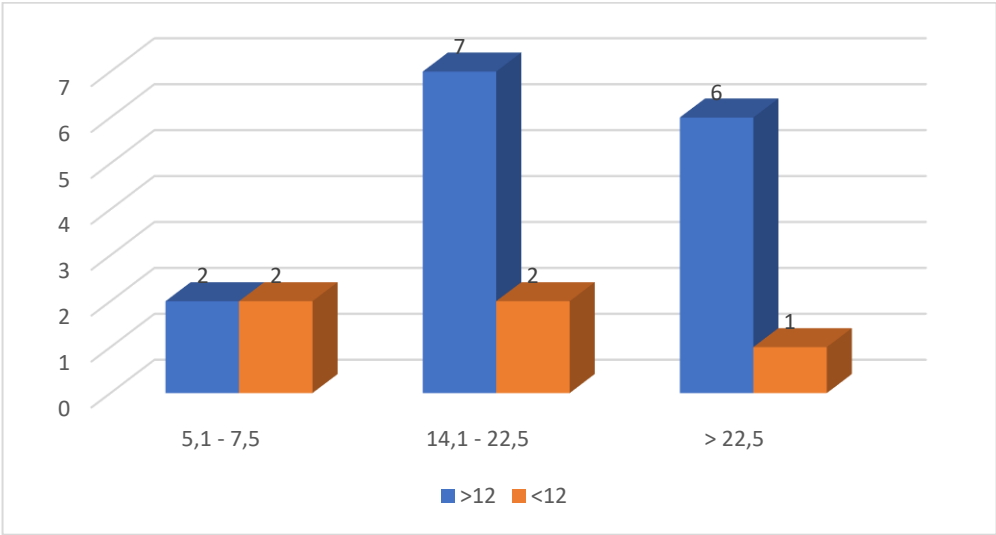


Figure 86 Relation between OCRA index and Hours per week

In the participants that work more than 12 hours per week are mostly in the indexes from 14.1 to >22.5. In the participants that work less than 12 hours are evenly distributed in the 3 levels described above.

4.1.5. Chi-Square

A chi-square test was applied to verify whether poor ergonomic practices are related to musculoskeletal problems.

Significance level of 0.05%.

4.1.5.1. Hypothesis

H0: There is no correlation between inadequate ergonomic practices and the development of musculoskeletal disorders.

H1: There is a correlation between inadequate ergonomic practices and the development of musculoskeletal disorders.

4.1.5.2. Observed Frequencies

Table 68 Observed frequencies with the Nordic questionnaire

Poor ergonomic practices	Influence on suffering MSDs			Total
	low influential	influential	high influential	
High number of repetitions	9	5	6	20
Lack of breaks	12	8	0	20
Sitting for long periods of time.	12	2	6	20
Working while standing for long periods of time.	6	4	10	20
Working in awkward postures	0	15	5	20
Perform Spinal Rotations	9	5	6	20
Keep the center of gravity away from your body.	16	4	0	20
Total	**64**	**43**	**33**	**140**
Frequency	0.46	0.31	0.23	1,00

4.1.5.3. Expected Frequencies

Table 69 Expected frequencies calculated with Chi-square

Poor ergonomic practices	Influence on suffering MSDs			Total
	low influential	influential	high influential	
High number of repetitions	9.14	6.14	4.72	20
Lack of breaks	9.14	6.14	4.72	20
Sitting for long periods of time.	9.14	6.14	4.72	20

Working while standing for long periods of time.	9.14	6.14	4.72	20
Working in awkward postures	9.14	6.14	4.72	20
Perform Spinal Rotations	9.14	6.14	4.72	20
Keep the center of gravity away from your body.	9.14	6.14	4.72	20
Total	**64**	**43**	**33**	**140**
Frequency	0.46	0.31	0.23	1.00

4.1.5.4. Chi-square Calculation

Parameters:

- Degrees of freedom: 12
- P-value: 0,05
- Chi-squeare level: 21.026

Table 70 Final punctuation of Chi-square

Poor ergonomic practices	**Influence on suffering MSDs**		
	low influential	**influential**	**high influential**
High number of repetitions	0.002	0.212	0.347
Lack of breaks	0.895	0.563	4.72
Sitting for long periods of time.	0.895	2.791	0.347
Working while standing for long periods of time.	1.079	0.746	5.906
Working in awkward postures	9.14	12.785	0.017
Perform Spinal Rotations	0.002	0.212	0.347
Keep the center of gravity away from your body.	5.149	0.746	4.72
Total	**17.162**	**18.055**	**16.404**
Total Chi-square	51.621		

Since the critical value is lower than the tabular value, the null hypothesis H0 is rejected, which implies accepting the alternative hypothesis H1.

4.2. DISCUSSION

The principal aim of this investigation was to determine the ergonomic risks of surgeons of "Hospital Teofilo Davila" for two principal reasons. First, the lack of ergonomic studies in general in Ecuador and the good uses of these tools. The other reason is that the few evaluations that are realized in the country are focused only on the industry, so the health area has not received good practices of work safety.

In the few studies found in Ecuador, almost nonexistent on ergonomics in the health sector, ergonomics studies were conducted on physiotherapists and nursing staff, some only theoretical on how bad postures could affect them and others that used only 1 ergonomic system for research (SOCEERGO, 2021). This is a very big slip for ergonomics studies in the country, as a qualitative assessment does not provide practical data to give a truthful answer.

According to Stephanie Hidalgo, that conducted an ergonomic evaluation of physiotherapists at the "Hospital de las F.F.A.A", concluded that the personnel who perform physical and rehabilitation therapies to other people are not aware of using ergonomic measures in their work. The 91% of the participants had a musculoskeletal disorder and 45% were at high risk. She recommends implementing ergonomic methods in hospitals for medical personnel and monitoring their health status (Hidalgo, 2015).

In relation of the results showed in this research, the 87.5% of the population suffers from any type of musculoskeletal disorder. In general, the most affected body parts were the neck and trunk (back), and few surgeons consider ergonomic measures or physical therapies to prevent or decrease the pain.

4.2.1. Nordic Questionnaire Modified

Eight surgeons were surveyed and studied during January and February of the present year, which are 6 men and 2 women, all of them right-handed of 5 different specialties. The interventions per week vary greatly, due to three surgeons have 10 operations, two surgeons have 6 operations, two surgeons have 4 operations and 1 surgeon have only 2 operations per week.

In addition, was found that regardless of gender and hours of work, the majority of surgeons suffer MSDs. The age variable was distinctive here because the population over 47 years old was whom more affectations had.

About the problems in the locomotor system and risk factors, the participants declared that the neck, upper back, lower back, and wrists were where they had the most discomfort and that the majority don't have any strategy to prevent these problems. To

check and investigate these data collected was used 3 ergonomic methods to ubicated the bad postures and the risk level. Also, a chi-square analysis was used to know if exists any relation of MSDs with this lack of practices of ergonomic measures in surgeons.

4.2.2. RULA method

The RULA method permits categorize the postures of the upper limbs of the body into 4 risk levels, where levels 3 and 4 indicate the highest risk and urgent changes in the task involved the tools used and the work environment (Mcatamney & Corlett, 1993). The results obtained were 85% of surgeons are in level 4 and 15% are in level 3, so investigation and changes are required immediately. This method focuses on the assessment of postural loading that all the doctors studied have excessive postural stress in neck, trunk, and wrist.

The relation between the RULA highest risk level (4) and variables showed that most of the population was male participants, over 47 years old and work more than 12 hours per week.

4.2.3. REBA method

The REBA method permits categorize the entire body postures into 5 risk levels, where the levels 2, 3, and 4 indicate the medium, high, and very high risk, respectively, thus immediate changes are required in the task involved the tools used and the work environment (Hignett & Mcatamney, 2000). The results obtained were 10% of surgeons are in level 4, 50% are in level 3 and 40% are in level 2, so action is necessary soon. This method focuses on the evaluation of forced postures that all surgeons studied have a high risk of posture-associated injuries, mainly of a musculoskeletal disorder (Mas & Antonio, 2015d).

The relation between the REBA risk levels and variables showed that most male participants and over 47 years old were in level 3. Most participants that work more than 12 hours per week were in level 2.

4.2.4. OCRA method

The OCRA checklist method permits categorize the repetitive work into 6 risk levels, where the levels between 11.1 to >22.5 index indicate an unacceptable level of risk, so the changes are required in the task involved the tools used and the work environment(Colombini et al., 2013). The results obtained were 20% of surgeons are between 5.1 to 7.5 that is an acceptable level, and action is not required, 45% are between 14.1 to 22.5 that is a medium level and 35% are >22.5 that is a high level, so action is necessary now. This method focuses on the evaluation of the repeatability of movements

that 80% of surgeons evaluated are recommended job upgrading, medical supervision, and training.

The relation between the OCRA risk levels and variables showed that most male participants, over 47 years old and that work more than 12 hours per week were in level 14.1 to 22.5.

4.2.5. Chi-Square

For the analysis of the relationship of the development of musculoskeletal problems was used Chi-square with a P-value of 0.05%. A tabular value of 51.621 was obtained, which is greater than the critical value 21.026, obtained from the table of critical values of the Chi-square distribution. Therefore, this value implies acceptance of the alternative hypothesis HE1, rejecting the null hypothesis HE0.

4.2.6. Comparations with other investigations

Table 71 Comparation between own and other investigations

Study	Method	Population	Country	Year
Own	RULA, REBA, OCRA	Surgeons	Ecuador	2021
1	NASA-tlx, REBA, Discomfort Corporal	Gynecologists	Chile	2020
2	Questionnaire	Laparoscopic surgery	Spain	2011
3	OWAS	Surgeons	Spain	2002
4	Questionnaire	Surgeons	Colombia	2012
5	Questionnaire	Dentists	Peru	2019
6	Questionnaire	Dental Students	Peru	2019

An important factor found in the studies was that there are few investigations about ergonomic in medical staff, especially in surgeons or inside the operating rooms. Also, in Ecuador, are almost nonexistent this type of studies.

The most of investigations did not use any ergonomic method, were qualitative, and did not focus on operating rooms. However, the other studies apply different ergonomic systems and emphasize the importance of these methods in health care. Additionally, it could be observed how in other countries outside of Ecuador ergonomics is regulated, mandatory, and has been working for several years.

CHAPTER 5

5.1. CONCLUSIONS

The results obtained in the present investigation allow us to establish that the surgeons the “Teofilo Davila” hospital are highly exposed to developing work-related musculoskeletal disorders, as indicated by the data obtained in the present study, 87.5% of the surveyed population has suffered pain or discomfort on at least one occasion.

It is important to mention that a varied group was evaluated in terms of gender, age, and working hours. Most of the population were male participants, over 47 years old, that work more than 12 hours per week and don´t use ergonomic measures or physical treatments.

The ergonomic evaluation realized showed the risk levels and factors of surgeons after the application of 3 ergonomic methods. All methods indicate that the 8 surgeons examined are in the highest levels of risk, whereby need an improvement of the workplace and required immediate action as these postures are causing injuries or may harm the surgeon in the future.

According to the postures evaluated most of them are inadequate postures, which the doctors keep for several hours a day. The body parts most affected are the neck, trunk, and wrist, this may be since they always keep their spine arched towards the front, which affects more the lumbar area, the neck is usually always at an incline and the wrists perform repetitive movements almost all the time of the intervention. Medical supervision, and improvement of the workplace by the occupational health department is recommended.

Other factors that increased the ergonomic risk are the difference in height among surgeons which makes it difficult to regulate appropriately the height of the surgical bed. Even when operating in a seated position, doctors maintain poor posture due to unstable seating and the bad conditions of biomedical equipment that decrease the good performance at the surgeries.

Finally, with the results obtained through the Chi-square test, the hypothesis proposed in the present study could be verified, since by obtaining a tabular value greater than the critical value, the null hypothesis could be rejected, accepting the alternative hypothesis and therefore being able to conclude that there is a correlation between inadequate ergonomic practices and the development of musculoskeletal disorders.

Surgical interventions require the performance of many tasks that include bending, twisting, static postures for a long time, and repetitive movements, putting surgeons at

risk and therefore considering them as a population susceptible to suffer from musculoskeletal disorders. Although their training gives them the tools to carry out preventive measures, many of them do not carry them out or are unaware of them, so it is necessary that ergonomics be taken as an important aspect of the method for preventing the development of musculoskeletal disorders related to their work.

5.2. OUTLOOK

The limitations encountered in the present investigation were the lack of participation of several surgeons and lack of access by the hospital. However, it was possible to perform a complete workup on a large majority of surgeons on duty during the months of work.

The application of ergonomic systems in the health sector, by the occupational safety department, should be established as a mandatory form of prevention for musculoskeletal injuries and focus on already acquired injuries.

For the future research project, the applications of actions and recommendations on the operating rooms, obtained by the results show in the present investigation are the priority for a treat the actual musculoskeletal disorders and prevent future complications. Some possible measures to be taken are:

- Know and use ergonomic measures to reduce MSDs
- Include active breaks, physiotherapeutic treatments, and physical activity in their working day
- Well distributed spaces, i.e., proper placement of biomedical devices to help maintain good posture
- Adequate illumination and seats
- Annual follow-ups of musculoskeletal problems of the medical staff with the help of ergonomics systems

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ANNEX

HOJA DE CAMPO

Observador: Kianny Sanchez A.

Fecha:

Hora:

Tipo de cirugía:

Cirujano (puesto):

Tiempo de cirugía:

Brazo	Antebrazo	Muñeca							
		1		2		3		4	
		Giro Muñeca		Giro Muñeca		Giro Muñeca		Giro muñeca	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	3	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	5	5	5	5
	2	4	4	4	5	5	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Tabla 1. Puntuación grupo A

Cuello	Tronco											
	1		2		3		4		5		6	
	Piernas		Piernas		Piernas		Piernas		Piernas		Piernas	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Tabla 2 Puntuación grupo B

Puntuación C: _____ + _____ + _____ = _____

Puntuación D: _____ + _____ + _____ = _____

Puntuación C	Puntuación D						
	1	2	3	4	5	6	7
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8	5	5	6	7	7	7	7

Tabla 3. Puntuación final

Annex 1 RULA Field Sheet

HOJA DE CAMPO REBA

Observador: Kianny Sanchez A.

Fecha:

Hora:

Tipo de cirugía:

Cirujano (puesto):

Tiempo de cirugía:

Tronco	Cuello											
	1				2				3			
	Piernas				Piernas				Piernas			
	1	2	3	4	1	2	3	4	1	2	3	4
1	1	2	3	4	1	2	3	4	3	3	5	6
2	2	3	4	5	3	4	5	6	4	5	6	7
3	2	4	5	6	4	5	6	7	5	6	7	8
4	3	5	6	7	5	6	7	8	6	7	8	9
5	4	6	7	8	6	7	8	9	7	8	9	9

Tabla 1. Puntuación grupo A

Brazo	Antebrazo					
	1			2		
	Muñeca			Muñeca		
	1	2	3	1	2	3
1	1	2	2	1	2	3
2	1	2	3	2	9	4
3	3	4	5	4	5	5
4	4	5	5	5	6	7
5	6	7	8	7	8	8
6	7	8	8	8	9	9

Tabla 2. Puntuación grupo B

Puntuación A: _____ + _____ + _____ + _____ = _____

Puntuación B: _____ + _____ + _____ + _____ = _____

Puntuación Final: _____ + _____ = _____

Puntuación A	Puntuación B											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Tabla 3. Puntuación C

Annex 2 REBA Field Sheet

HOJA DE CAMPO OCRA

Observador: Kianny Sanchez A.

Fecha:

Hora:

Tipo de cirugía:

Cirujano (puesto):

Tiempo de cirugía:

Indice Check List

ICKL = (_____ + _____ + _____ + _____ + _____) * _____ = _____

- **Factor de Recuperación**

FR = _____

- **Factor de Frecuencia**

FF = Max (_____; _____) = _____

- **Factor de Fuerza**

Intensidad: _____

FFz = _____

- **Factor de posturas y movimientos**

Puntuación hombro = _____

Puntuación codo = _____

Puntuación muñeca = _____

Puntuación mano = _____

Puntuación estereotipados = _____

FP = Max (_____; _____; _____; _____) + _____ = _____

- **Factor de riesgos adicionales**

Puntuación Socio-organizativos = _____

Puntuación Físico-mecánicos = _____

FC = _____ + _____ = _____

- **Multiplicador de Duración**

MD = _____

Tiempo Neto de Trabajo Repetitivo

TNTR = _____ - (_____ + _____ + _____) = _____

Tiempo Neto del Ciclo de Trabajo

TNC = 60 * _____ / _____ = _____

Annex 3 OCRA Field Sheet

Date: _____

NORDIC QUESTIONNAIRE

Section A: Personal Data

Name: _____ ID: _____

Age: _____ Gender: F__ M__ **Occupation**: _____

Hours per week: _____ Physically active: Yes___ No___

Do you use any ergonomic measures in the operating room?

a. Yes, Which? _____
b. No

Do you receive any physical therapy treatment?

a. Yes
b. No

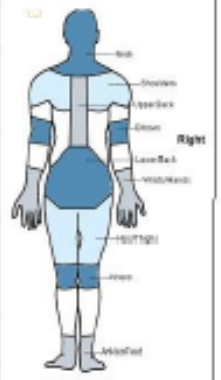
Section C: Risk Factors

1=low influential 2=influential 3=high influential

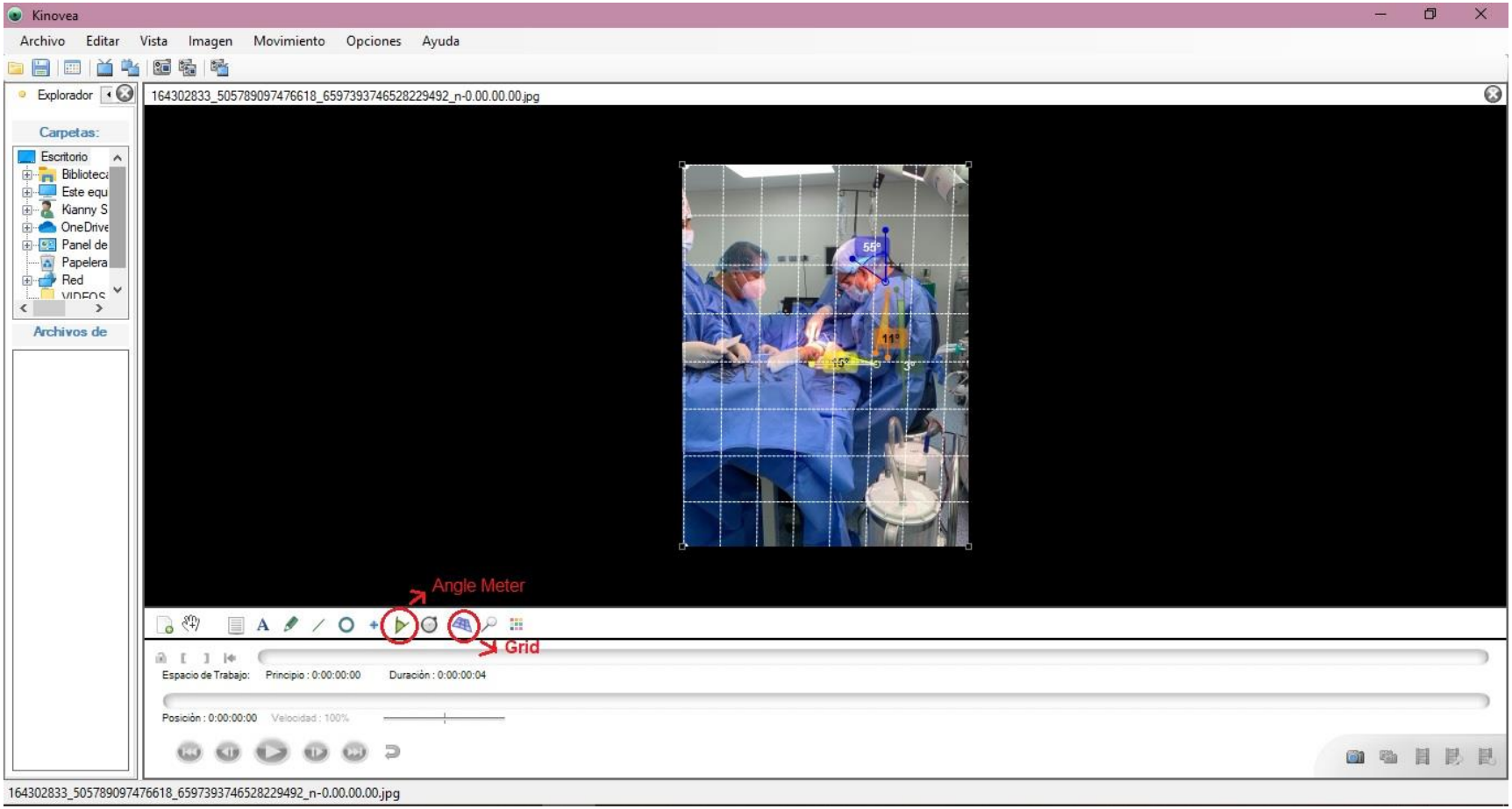
Influential Risk	1	2	3
High number of repetitions			
Lack of breaks			
Sitting for long periods of time			
Working while standing for long periods of time			
Working in awkward postures			
Perform Spinal Rotations			
Keep the center of gravity away from your body			

Section B: Problems in The Locomotor System

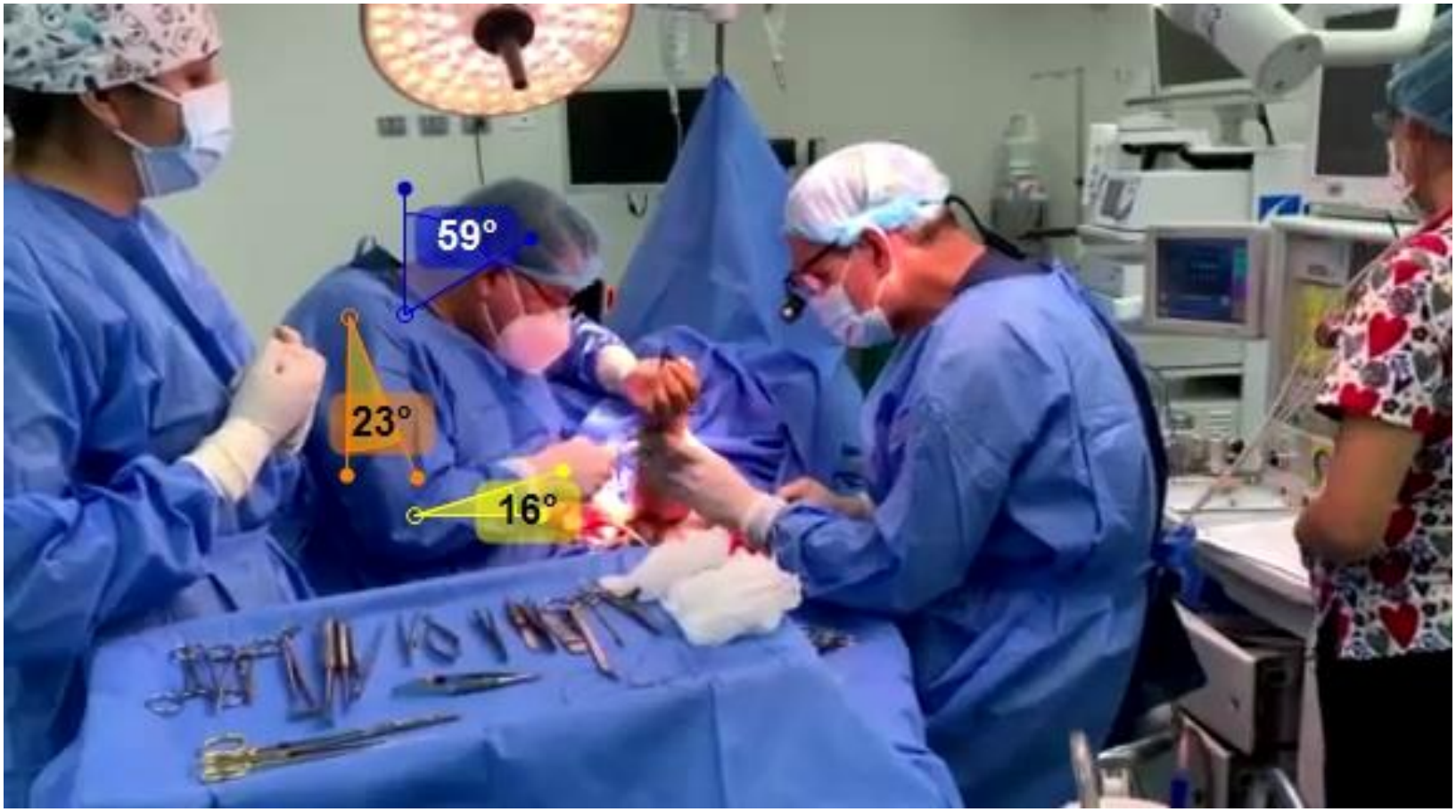
To Be Answered by Everyone		To be Answered by those who had a trouble
Have you at any time during the last 12 months had trouble (ache, pain, discomfort, numbness) in:		Have you had trouble at any time during the last 12 months? (Prevent do your normal work)
Neck	☐ Yes ☐ No	☐ Yes ☐ No
Shoulders	☐ Yes ☐ No ☐ Right ☐ Left	☐ Yes ☐ No
Elbows	☐ Yes ☐ No ☐ Right ☐ Left	☐ Yes ☐ No
Wrists/Hands	☐ Yes ☐ No ☐ Right ☐ Left	☐ Yes ☐ No
Upper Back	☐ Yes ☐ No	☐ Yes ☐ No
Lower Back	☐ Yes ☐ No	☐ Yes ☐ No
One or Both Hips/Thighs	☐ Yes ☐ No	☐ Yes ☐ No
One or Both Knees	☐ Yes ☐ No	☐ Yes ☐ No
One or Both Ankles/Feet	☐ Yes ☐ No	☐ Yes ☐ No



Annex 4 Nordic Questionnaire



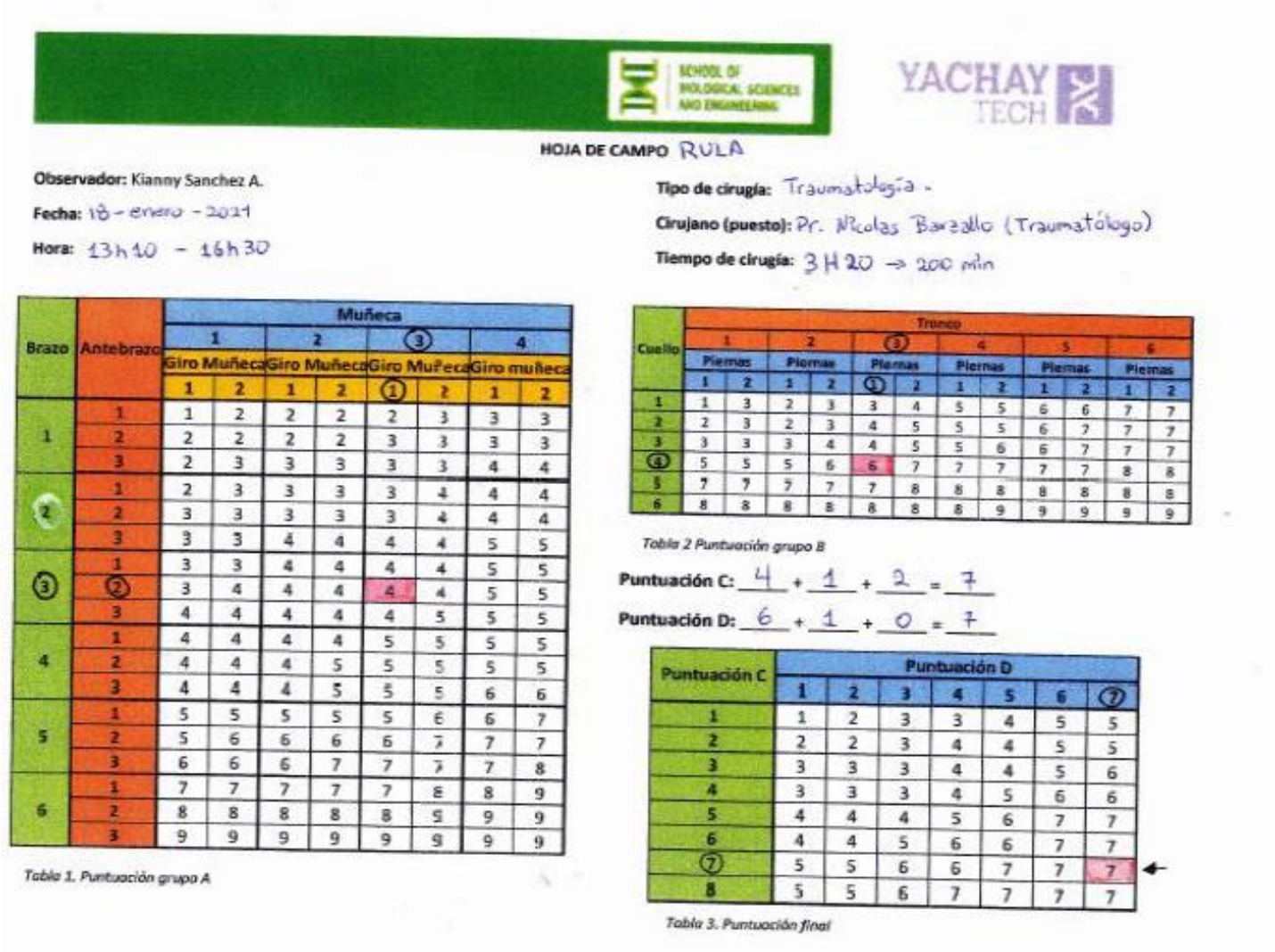
Annex 5 angle measurement in the Kinovea software



Annex 6 angle taking in general surgery

Annex 7 angle taking in laparoscopic surgery

Annex 8 Medical staff



HOJA DE CAMPO RULA

Observador: Kianny Sanchez A.

Fecha: 18 - enero - 2021

Hora: 13h10 - 16h30

Tipo de cirugía: Traumatología -

Cirujano (puesto): Dr. Nicolas Barzallo (Traumatólogo)

Tiempo de cirugía: 3H20 → 200 min

Brazo	Antebrazo	Muñeca							
		1		2		3		4	
		Giro Muñeca		Giro Muñeca		Giro Muñeca		Giro muñeca	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	3	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	5	5	5	5
	2	4	4	4	5	5	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Tabla 1. Puntuación grupo A

Cuello	Tronco											
	1		2		3		4		5		6	
	Piernas		Piernas		Piernas		Piernas		Piernas		Piernas	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Tabla 2 Puntuación grupo B

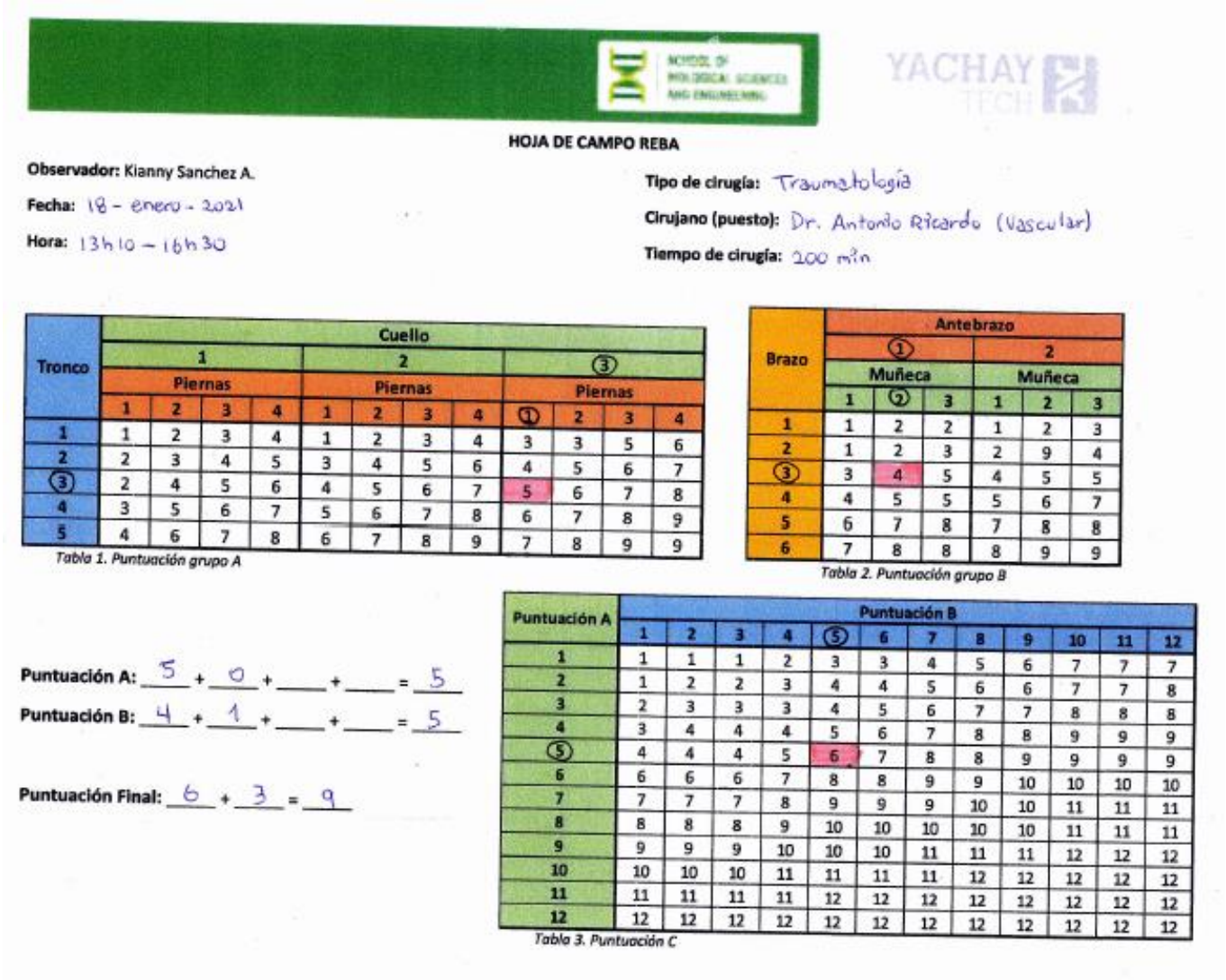
Puntuación C: 4 + 1 + 2 = 7

Puntuación D: 6 + 1 + 0 = 7

Puntuación C	Puntuación D						
	1	2	3	4	5	6	7
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8	5	5	6	7	7	7	7

Tabla 3. Puntuación final

Annex 9 RULA field sheet example



HOJA DE CAMPO REBA

Observador: Kianny Sanchez A.

Fecha: 18 - enero - 2021

Hora: 13h10 – 16h30

Tipo de cirugía: Traumatología

Cirujano (puesto): Dr. Antonio Ricardo (Vascular)

Tiempo de cirugía: 200 min

Tronco	Cuello 1 – Piernas 1	Cuello 1 – Piernas 2	Cuello 1 – Piernas 3	Cuello 1 – Piernas 4	Cuello 2 – Piernas 1	Cuello 2 – Piernas 2	Cuello 2 – Piernas 3	Cuello 2 – Piernas 4	Cuello 3 – Piernas 1	Cuello 3 – Piernas 2	Cuello 3 – Piernas 3	Cuello 3 – Piernas 4
1	1	2	3	4	1	2	3	4	3	3	5	6
2	2	3	4	5	3	4	5	6	4	5	6	7
3	2	4	5	6	4	5	6	7	5	6	7	8
4	3	5	6	7	5	6	7	8	6	7	8	9
5	4	6	7	8	6	7	8	9	7	8	9	9

Tabla 1. Puntuación grupo A

Brazo	Antebrazo 1 – Muñeca 1	Antebrazo 1 – Muñeca 2	Antebrazo 1 – Muñeca 3	Antebrazo 2 – Muñeca 1	Antebrazo 2 – Muñeca 2	Antebrazo 2 – Muñeca 3
1	1	2	2	1	2	3
2	1	2	3	2	9	4
3	3	4	5	4	5	5
4	4	5	5	5	6	7
5	6	7	8	7	8	8
6	7	8	8	8	9	9

Tabla 2. Puntuación grupo B

Puntuación A: 5 + 0 + ____ + ____ = 5

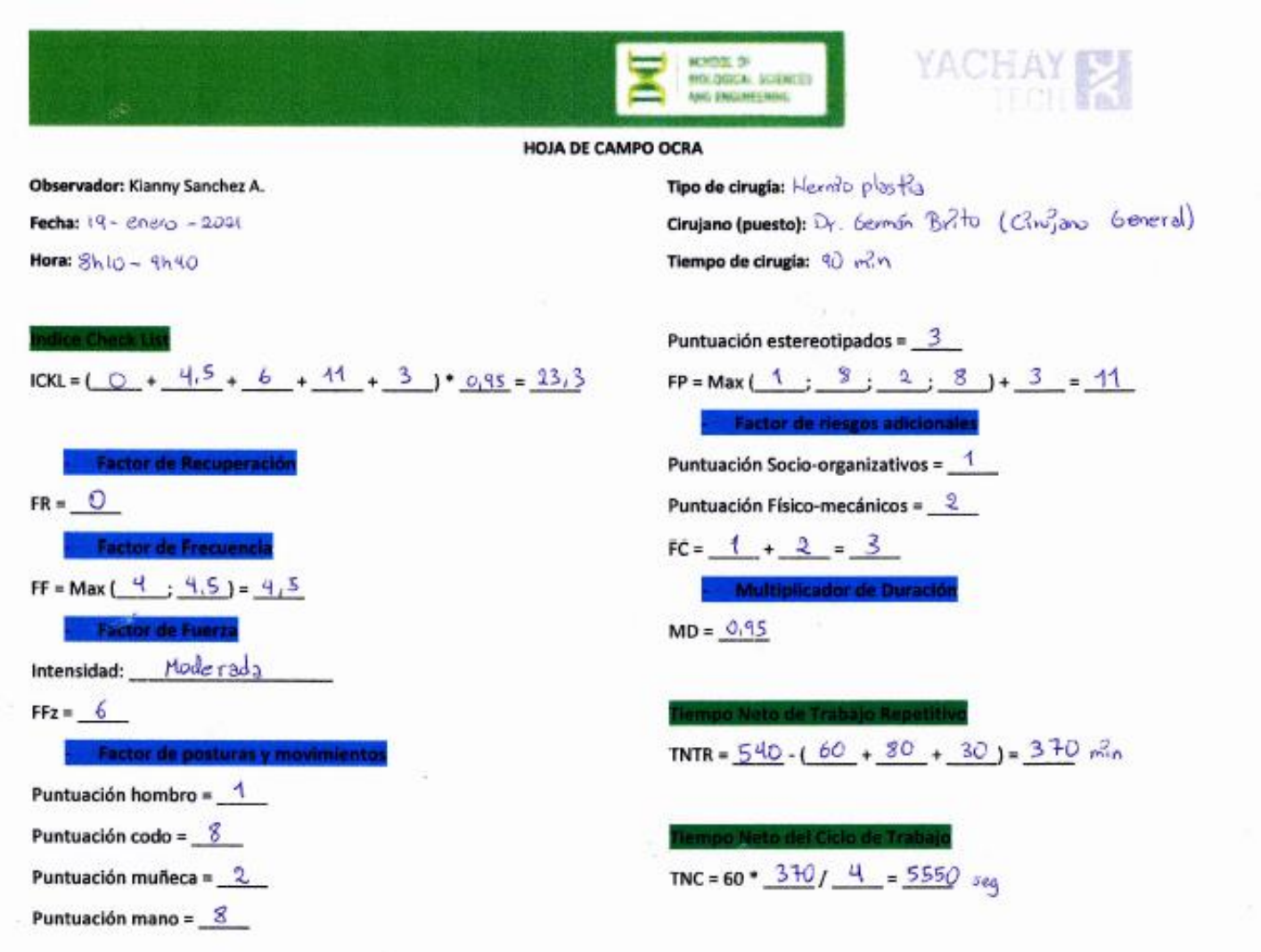
Puntuación B: 4 + 1 + ____ + ____ = 5

Puntuación Final: 6 + 3 = 9

Puntuación A	Puntuación B 1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Tabla 3. Puntuación C

Annex 10 REBA field sheet example



HOJA DE CAMPO OCRA

Observador: Kianny Sanchez A.

Fecha: 19 - enero - 2021

Hora: 8h10 - 9h40

Tipo de cirugía: Hernia plastia

Cirujano (puesto): Dr. Germán Brito (Cirujano General)

Tiempo de cirugía: 90 min

Indice Check List

ICKL = (0 + 4,5 + 6 + 11 + 3) * 0,95 = 23,3

Factor de Recuperación

FR = 0

Factor de Frecuencia

FF = Max (4 ; 4,5) = 4,5

Factor de Fuerza

Intensidad: Moderada

FFz = 6

Factor de posturas y movimientos

Puntuación hombro = 1

Puntuación codo = 8

Puntuación muñeca = 2

Puntuación mano = 8

Puntuación estereotipados = 3

FP = Max (1 ; 8 ; 2 ; 8) + 3 = 11

Factor de riesgos adicionales

Puntuación Socio-organizativos = 1

Puntuación Físico-mecánicos = 2

FC = 1 + 2 = 3

Multiplicador de Duración

MD = 0,95

Tiempo Neto de Trabajo Repetitivo

TNTR = 540 - (60 + 80 + 30) = 370 min

Tiempo Neto del Ciclo de Trabajo

TNC = 60 * 370 / 4 = 5550 seg

Annex 11 OCRA field sheet example

Date: 19 - enero - 21

NORDIC QUESTIONNAIRE

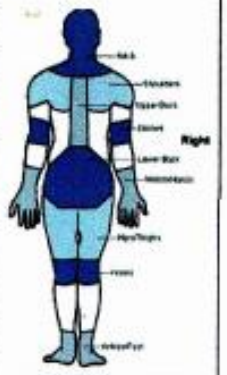
Section A: Personal Data

Name: Christian Rios ID: 1714228416 Age: 39 Gender: F __ M ✓

Occupation: Residente Hours per day: 4-5 Hours per week: 13

Section B: Problems in The Locomotor System

To Be Answered by Everyone		To be Answered by those who had a trouble
Have you at any time during the last 12 months had trouble (ache, pain, discomfort, numbness) in:		Have you had trouble at any time during the last 12 months? (Prevent do your normal work)
Neck	☐ Yes ☒ No	☐ Yes ☒ No
Shoulders	☒ Yes ☐ No ☒ Right ☐ Left	☐ Yes ☒ No
Elbows	☐ Yes ☒ No ☐ Right ☐ Left	☐ Yes ☒ No
Wrists/Hands	☐ Yes ☒ No ☐ Right ☐ Left	☐ Yes ☒ No
Upper Back	☐ Yes ☒ No	☐ Yes ☒ No
Lower Back	☒ Yes ☐ No	☐ Yes ☒ No
One or Both Hips/Thighs	☐ Yes ☒ No	☐ Yes ☒ No
One or Both Knees	☐ Yes ☒ No	☐ Yes ☒ No
One or Both Ankles/Feet	☐ Yes ☒ No	☐ Yes ☒ No



Section C: Risk Factors

1. **Do you use any ergonomic measures in the operating room?**
   - (a) Yes, Which? Acomodar dispositivo broncoscopio
   - b. No
2. **Do you receive any physical therapy treatment?**
   - a. Yes
   - (b) No
3. **Are you physically active?**
   - (a) Yes
   - b. No
4. **Do you know about Ergonomic systems?**
   - (a) Yes
   - b. No

Annex 12 Nordic questionnaire example

Annex 13 picture takin

Machala, 19 de enero de 2021

Acuerdo de Confidencialidad

Yo, **Kianny Miroslava Sanchez Armijos**, en mi carácter de estudiante de la Universidad Yachay Tech, a cargo del proyecto de grado titulado: "**Evaluación Ergonómica del Personal Médico en Cirugía General y Laparoscópica**", mayor de edad y en pleno uso de mis facultades, hago constar que me comprometo a resguardar, mantener la confidencialidad y no hacer mal uso de los documentos, reportes, archivos físicos y electrónicos de la información recabada, estadísticas o bien, cualquier otro registro o información relacionada con el estudio mencionado a mi cargo, así como a no difundir, distribuir o comercializar con los datos personales contenidos en los sistemas de información; Salvo el resultante a constar en el texto del proyecto de investigación mencionado.

Estando en conocimientos de que en caso de no dar cumplimiento se procederá a las sanciones civiles, penales o administrativas que proceda de conformidad con los dispuesto en las Políticas del Hospital, Constitución de la República del Ecuador, Ley Orgánica de Salud, Código Integral Penal y demás disposiciones aplicables en la materia.

Nombre: Germán Brito Lara
C.I.: 0959449521

Nombre: Christian Ríos
C.I.: 1714228416

Nombre:
C.I.:

Nombre:
C.I.:

Annex 14 Confidentiality Agreement