DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

RISK ASSESSMENT FOR MUSCULOSKELETAL DISORDERS IN AN INTERNATIONAL MANUFACTURING FIRM BY RAPID ENTIRE BODY ASSESSMENT METHOD

by

Yeşim HAZIRBULAN

October, 2019

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RISK ASSESSMENT FOR MUSCULOSKELETAL DISORDERS IN AN INTERNATIONAL MANUFACTURING FIRM BY RAPID ENTIRE BODY ASSESSMENT METHOD

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"RISK ASSESSMENT FOR MUSCULOSKELETAL DISORDERS IN AN INTERNATIONAL MANUFACTURING FIRM BY RAPID ENTIRE BODY ASSESSMENT METHOD"** completed by **YEŞİM HAZIRBULAN** under supervision of **PROF.DR. HASAN SELİM** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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RISK ASSESSMENT FOR MUSCULOSKELETAL DISORDERS IN AN INTERNATIONAL MANUFACTURING FIRM BY RAPID ENTIRE BODY ASSESSMENT METHOD

ABSTRACT

Occupational diseases and disorders are among major common problems in society. Today, work-related Musculoskeletal Disorders (MSDs) are important health problems and represent the majority of occupational pathologies. MSDs result in work restrictions, decrease in quantity and quality of work, productivity, quality of life, and increase in loss of working time, wage compensations and medical expenses. Uncomfortable working postures cause MSDs by increasing biomechanical overload in the different body regions, and consequently increase work accidents. Therefore, analysis of the postural attitudes of the employees during the interaction with working environment is crucial in prevention of ergonomic risks caused by biomechanical overload. This study aims to examine the risk factors of MSDs associated with different work postures of the employees in an international manufacturing firm by using ergonomic evaluation criteria. To this aim, the risky production divisions of the firm are determined by a survey firstly. Then, risk levels of the tasks for the selected production divisions are measured by using Rapid Entire Body Assessment (REBA) method, which is a common ergonomic tool used to facilitate the measurement and evaluation of whole-body postural risks associated with job tasks. The analysis reveal that some employees adopted unfavorable working postures making them susceptible to moderate to high risk of future musculoskeletal disorders. The measures to be taken towards proper working are suggested to the management of the firm.

Keywords: Ergonomic risk assessment, Musculoskeletal disorders, REBA

ULUSLARARASI BİR ÜRETİM FİRMASINDA KAS-İSKELET SİSTEMİ BOZUKLUKLARINDA HIZLI TÜM VÜCUT DEĞERLENDİRME YÖNTEMI İLE RİSK DEĞERLENDIRMESİ

ÖZ

Meslek hastalıkları toplumda sık karşılaşılan sorunlar arasındadır. Günümüzde Mesleki Kas-İskelet Sistemi Rahatsızlıkları (MKİSR) önemli sağlık sorunlarıdır ve mesleki patolojilerin çoğunu temsil eder. MKİSR, iş kısıtlamaları, iş miktarının ve iş kalitesinin azalması, verimlilik, yaşam kalitesi ve zaman kayıpları, tazminatlar ve tıbbi harcamalarla sonuçlanmaktadır. Uygun olmayan çalışma pozisyonları, farklı vücut bölgelerinde aşırı yük oluşturarak MKİSR'na neden olur ve sonuç olarak iş kazalarını arttırır. Bu nedenle, çalışanların çalışma ortamı ile etkileşimi sırasındaki pozisyonlarının analizi, aşırı biyomekanik yüklenmeden kaynaklanan ergonomik risklerin önlenmesinde çok önemlidir. Bu çalışma, uluslararası bir imalat firmasında çalışanların farklı iş pozisyonlarıyla ilişkili MKİSR risklerini ergonomik değerlendirme kriterleri kullanarak incelemeyi amaçlamaktadır. Bu amaçla, öncelikle firmanın riskli üretim bölümleri anket yöntemi kullanılarak belirlenmiştir. Ardından, seçilen bölümlerde gerçekleştirilen görevlerin risk seviyeleri, tüm vücuda ilişkin duruş risklerinin ergonomik açıdan ölçülmesi ve değerlendirilmesinde yaygın olarak kullanılan Hızlı Tüm Vücut Değerlendirme (REBA) yöntemi kullanılarak ölçülmüştür. Yapılan analizler, bazı firma çalışanlarının, MKİSR açısından orta ve yüksek seviyelerde risk altında olmalarına yol açan elverişsiz çalışma pozisyonlarına sahip olduklarını ortaya koymuştur. Söz konusu riskleri azaltacak uygun çalışma pozisyonlarını sağlamaya yönelik yönelik önlemler firma yöneticileri ile paylaşılmıştır.

Anahtar Sözcükler: Ergonomik risk değerlendirme, Kas-iskelet sistemi rahatsızlıkları, REBA

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INTRODUCTION

Today, rapidly developing technology brings important changes in working life. As a result of these changes, there is rapid and intensive mechanization in the production processes. This change diversifies the skills of the people actually working in the production processes in terms of physical and intellectual aspects and creates significant pressure on the employees. This situation has negative effects on employee productivity. Ergonomics have gained importance in eliminating and minimizing these effects. In this context, we can say that one of the factors affecting productivity is ergonomics, in other words, factors that are related to the harmony between the employee and the working environment (Demir, 2006; Kaya, 2008).

1.1 Ergonomics

1.1.1 Definition of Ergonomics

Ergonomics is an interdisciplinary branch of science that examines the relations between individual and the equipment or the relations between individual and work environment. Ergonomics, also known as "Human Engineering" or "Business Science" examines the physiological, biological, anatomical and other characteristics of a human, in order to adapt the human, machine and work to be integrated at their best. In order for humans to be more productive in their jobs, ergonomics must fulfill the following conditions.

- Ensure that the employee works in health and safety at work.
- Ensure that the work is designed in accordance with human anthropometric measures, body strength and personal characteristics.
- Ensure that every tool, machine, hardware, and equipment are designed to be compatible with human abilities.
- Ensure an environment that is positive in terms of psychosocial and humane working life conditions.

In order to fulfill these functions, ergonomics examines the physiological and biological characteristics of human, energy requirements, the relation of energy with the work, nutrition and its relation with the work, fatigue, human-machine systems, and working conditions; makes noise, light and color study; contributes to the determination of working and rest periods.

According to another definition, ergonomics is the science of adapting workplace requirements and job demands to the capacities of employees. The principles of ergonomics are used to increase the harmony between the employee and the workplace. Ergonomics as a practical approach; manages the relations with human, equipment, business processes, and business environment.

According to another definition, ergonomics (or human factor engineering) is a discipline that takes into account the relationships between employees and individuals in the system and is a science that applies theories and principles, data and methods in design to optimize human health, safety, and system performance (Kahraman, 2012).

In order for people to work in their workplaces healthy, safe and efficient, factors such as sound, lighting, environment temperature and work organization and management systems should be arranged on the structural, dimensional and psychological characteristics of human beings. The main task of ergonomics is to carry out a work arrangement for the above purposes. In a sense, we can define ergonomics as the arrangement of the work in accordance with the characteristics of the human being. The word ergonomics consists of the words “Ergon" and "Nomic" in Greek. Ergon means business and nomic means rule.

Ergonomics, taking into account the anatomical characteristics, anthropometric properties, physical capacities and tolerances of people, aims to reveal the basic laws of system efficiency and human-machine-environment adaptation in the face of organic and psychosocial stresses which may be affected by all factors in the industrial work environment (Kardaş, 2011).

1.1.2 Historical Development of Ergonomics

The main events in the development of ergonomics can be listed as follows.

- F.W. Taylor developed various theories in order to improve "work order" and make employees work more efficiently.
- In the 1910s, Mr. & Mrs. Gilberth developed time & Motion Study.
- Munsterberg performed "Psychology in Industrial Activities" study in 1913.
- Fatigue Board and National Institute of Industrial Psychology are established in the UK.
- The Oxford Meeting of the Ergonomics Research Council was arranged in 1949 with transition to multi-disciplinary research and understanding that only the psychological approach would not be sufficient (Ayanoğlu, 2007)

Ergonomics in Turkey is relatively new. The idea of ergonomics, though indirectly, was first addressed in the Faculty of Agriculture at Ankara University with the establishment of the chair of Live Force Resources in Agriculture. Until 1969, this force was generally studied on the sources of mechanical force. In 1971, ergonomics was taken into the education program at the Department of Industrial Engineering of Middle East Technical University, under the name of Human Factor Engineering.

In 1975, a laboratory was established with instruments brought from abroad. In the 1980s, Dokuz Eylül University, Department of Industrial Engineering, did not only introduce the Ergonomics courses supported by a large number of contemporary laboratory instruments but also organized the 1st and 2nd Turkish-German Ergonomics Symposiums with the help of the West German Cultural Attaché in Izmir in 1984 and l986, respectively. The National Productivity Center (MPM) has made important contributions in Turkey in introducing the subject of ergonomics to the business world. In addition to emphasizing ergonomics in the seminars such as, Improvement of Physical Environment in Workplaces, Contribution of Industrial Engineering to Enterprises, MPM experts prepared books on this subject. Since 1987, the MPM has contributed to the field by organizing ergonomics congress every two years. A total of seven ergonomics congresses were held, in which practitioners and researchers from the business world and academia presented a large number of papers. In spite of these efforts of MPM, it would not be right to say that ergonomics is fully recognized and applied in Turkey. Although the studies in the universities continues, the ergonomics cannot be used sufficiently in the public sector. However, several countries have given great importance to ergonomics after World War II and have made great progress in the field (Kardaş, 2011).

Initial research on ergonomics is economics-based and is intended to increase productivity only. At first, the human was seen as a machine and to increase its productivity it's perceived that human must keep up with the pace of machine to make more profit or make more product. However, it was later understood that it was wrong to see man as a machine and that the human working over his power would get tired and cause accidents. Nowadays, in order to purify the working environment from the dangers and accidents that can come to the human being, it is being tried to be transformed into an environment that will please and delight the people (Ayanoğlu, 2007).

1.1.3 Objectives of Ergonomics in the Workplace

In order to maintain the competitive advantage of the workplaces, production rate and technology advancements need to be increased. Today, the jobs/tasks may have the following characteristics.

- Frequent heavy lifting, handling, pushing or pulling is carried out without any assistance from any equipment.
- There exist jobs that require the worker to repeat the same task for a long time.
- There exist more working days requiring for more than 8 hours.
- There exist works that need to be done quickly.

The combination of negative factors such as improper machine tool and workplace design, as well as those mentioned above increase the probability of work accidents. Ergonomists, industrial engineers, occupational health and safety specialists, and other experts advise that when the principles of ergonomics are applied in the workplaces, the current pressure in the workplaces will be reduced and serious injuries will be prevented.

The improvements that may occur as a result of ergonomics practices in the workplaces can be summarized as follows (Ayanoğlu, 2007).

- Ensuring occupational health and safety
- Prevention of labor losses
- Reducing fatigue and work stress, increasing motivation
- Prevention of occupational accidents and risks
- Increasing efficiency and quality
- Increasing production by making workers more comfortable
- Improve production quality by making fewer errors with automated processes that require less physical power
- Reducing workers' health problems and preventing labor losses
- Reduce the costs of health and firing for employees

Establishing the balance between employee skills and job requirements improves workers' health and safety, efficiency and the quality of working life (Akay, 2003; Kaya, 2008). The harmony between human-equipment and working environment has great importance in the success of organizations. In terms of the compliance of the employees with the working environment and the equipment, as well as the suitability of the tools for the employees, the enterprises organize various training and development programs while making physical arrangements in the work environment. In other words, in order for the employees to work effectively, ergonomic arrangements should be made (Demir, 2003).

Despite the transition to automation as a result of technological developments, industrial enterprises still need labor. Improper work postures can cause musculoskeletal system disturbance and production inefficiency. The main objective of ergonomics is to reach maximum performance with minimum manpower cost (stress, strain, fatigue, accidents). Therefore, studying and examining working postures became an important subject for the businesses and employees (Akay, Dağdeviren & Kurt, 2003). This study explains in the subsections the working posture, the importance of the working posture, the diseases caused by improper working postures, how a good working posture should be and how the posture can be improved.

1.1.4 Ergonomic Disorders

Employees are exposed to various hazards and risks arising from the work done and the working environment. Work accidents occur due to unsafe conditions or behaviors in the workplace. As a result of work accidents, injuries, limb losses and deaths may occur. According to research conducted by the International Labor Organization, 270 million people are exposed to occupational accidents and 160 million people are exposed to occupational diseases every year. 2.2 million people die due to accidents and occupational diseases. Due to these accidents and diseases, the economic loss suffered by the global economy is 4% of the Gross Domestic Product (GDP), which is 20 times more than the total of the official development support.

Due to the material and moral losses caused by occupational accidents and diseases, today more importance to be given to occupational health and safety. Investigations on the causes of occupational accidents reveal that most of the work accidents are preventable. To prevent occupational accidents and diseases, proactive actions should be applied. One of the proactive actions is the risk assessment at workplaces (Semerci, 2012). MSDs, which are among the most important health disorders and causes a decrease in productivity, can be avoided with education about ergonomics (Özcan, 2007 & Kesiktaş, 2007). To establish public awareness, employees, employers and professionals and organizations dealing with occupational health and safety should be informed about MSDs and its prevention strategies.

Research and development activities should be carried out with the participation of relevant governmental institutions, universities and industry, especially the Ministry of Labor and Social Security, and the results should be shared (Özcan, 2007 & Kesiktaş, 2007).

The following disorders are the examples of occupational disorders.

- Pain in the knees of the maids,
- Disturbance in the thumb of dishwashers,
- Authors' hand cramps,
- Disturbance on the shoulders of garbage collectors,
- Tensions in the wrists of tailors.

These historic occupational disorders are still present. Such disorders are a part of the category of extensive injuries and disorders called musculoskeletal disorders. Musculoskeletal disorders usually do not occur by severe traumas, but occur slowly in the soft tissues, such as the muscles, tendons, ligaments, joints, cartilages, and recurrent injuries in the nervous system. Musculoskeletal disorders can be seen from office workers to industrial workers or athletes and hobbyists. Work-related MSDs occur when the physical abilities of the workers do not match the physical requirements of the work. In other words, they emerge as a result of the work done in the workplace with a weak ergonomic order (Ayanoğlu, 2007).

1.1.5 Working Positions

The human body has a movement system composed of bones attached to the joints and supported by muscles. The bone roof called the skeleton, protects sensitive internal organs from external influences, while, with the help of muscles, it can move around the joints in certain directions. The moving parts operate according to various leverage laws. The moving surfaces of the joints connecting the bones are covered with cartilage tissue. The faces of the joints are smooth, slippery and durable. The movement of bones that are around the joint is provided by muscles help. The muscles relax or contract in a harmonious way, allowing the whole or part of the body to move in various directions, especially forward-backward, left-right or up-down.

Bones that forming, moving, shaping the body and protecting the organs are called the skeleton. The skeleton consisting of long, short and flat bones is divided into three parts: the head, the torso and the perimeter (arms and legs) (Kardaş, 2011).

Posture is defined as the alignment of the body, head, torso, arm and leg members in the void. The working posture is defined as the alignment of the body, head, torso, arms, and legs with respect to the work done and the characteristics of the work. Improper stances are defined as the deviation of one or more limbs from the stationary body posture. In the 18th century, with the Ramazzini's statements about harmful results of irregular and violent movements and unnatural body postures, the importance of proper body posture has gained importance. He also stated that various musculoskeletal disorders occur in operators who perform highly stationary tasks, and that may cause serious disturbance in the long term.

Minimizing the disturbance experienced during the work and ensuring healthy work are as important as the performance of the work (Akay, Dağdeviren & Kurt, 2003).

1.1.6 Occupational Health and Work-related Musculoskeletal Disorders

The World Health Organization (WHO) and the International Labor Organization (ILO) declare that in all professions, physical, mental, social well-being of the workers to maximize the level, to maintain this level, to prevent the deterioration of the health of workers due to the working conditions of health workers, to protect them from the dangers of the factors, to place the workers in the most suitable professional environments for their physiological and psychological conditions and to maintain these conditions there must be a harmony between the work and the employee.

In TS 18001 Occupational Health and Safety Management Systems published in 2004 by Turkish Standards Institute, occupational health and safety is defined as the factors affecting the health and safety of employees, temporary workers, contractor personnel, visitors and other people in the field.

There exists various definitions of occupational health and safety in the literature. Occupational health and safety is the work to ensure the necessary legal, technical and medical measures to be taken in order to prevent physical and mental damage from dangers arising from the work of the employees in the workplace (Baradan, 2009). Investigations of dangers in the workplaces related to production, machinery and facility is called *occupational safety*.

Employees face various dangers and risks in the workplaces. Danger is the conditions that may cause injuries or illness, damage to property or material, damage to the workplace environment. Risk is the combination of the probability of occurrence of a dangerous event and its consequences. The word “risk” is derived from the ancient Italian word risicare, which means courage. In this context, the risk is a choice rather than a fate. The courageous steps are the story of the risk. This story is a description of what human beings are (Pickett, 2010).

Risk assessment is the whole process used to estimate the magnitude of the risk and decide whether to tolerate risk. Safety is an absence of risk of harm that cannot be tolerated by any means. Tolerable risk is the risk that the organization can tolerate according to legal obligations and its OHS policies.

Work-related MSDs resulting from work-related activities are a common health problem in industrialized countries and are a leading cause of disability. First, they hold the waist, neck, hands, wrists, elbows, and shoulders. MSDs, which negatively affect the job satisfaction, morale, and productivity of the employee, have a high cost to society due to working day loss and insurance compensation payments (Özcan, 2007).

Ergonomic factors that play role in the formation of work-related MSDs include physical factors (force exertion, repetitive movements, inappropriate and stable postures), environmental factors (vibration, cold or extreme heat, poor lighting, high noise levels, chemicals), factors related to organization and psychosocial factors (overwork, rapid and repetitive monotonous work, lack of support from peers and supervisors) (Özcan, 2007; Ayanoğlu, 2007; Buker, 2006). It was determined that the MSDs faced by medical workers were concentrated in the load-bearing parts of the body and that the painful situations increased at the end of the working hours.

The main health problem related to work is upper extremity pain. Work-related upper-extremity MSDs often include neck-shoulder pains, carpal tunnel syndrome, tendinitis, lateral epicondylitis, medial epicondylitis, tenosynovitis and trigger finger (Yılmaz, 2006; Tamara, 2010).

Early symptoms of musculoskeletal damage may occur suddenly or slowly over a long period of time (Akay, 2003). Early warning signs are swelling, numbness, redness, tingling and weakness. Early recognition of the symptoms of occupational musculoskeletal damage is important in reducing future damage and providing rapid treatment.

Excessive force against a weight can pose a risk to muscles and tendons. Lifting, pushing, carrying, pulling, holding, holding a moving object, holding slippery objects, bending down tools, using vibratory tools or equipment, badly worn or improper gloves may be a risk. The human body is biomechanically adapted to different postures and activities. It works best by moving and changing position. The muscles are designed to contract actively, and if the muscles will be stretched for a long time, pumping and blood flow will also deteriorate. Standing in a tilted position for long hours can cause fatigue in muscles and a decrease in blood flow due to lack of pumping. When working in the same position, some areas are at greater risk because of the position of the body. The riskiest areas are the neck, back, waist, shoulders, elbows, wrist, and fingers (Yörükoğlu, 2007).

In Turkey, many musculoskeletal diseases involving the lower back, neck, upper and lower extremities are considered to be occupational diseases by law. Unfortunately, there is no data about the frequency, risk factors, working day loss, insurance claims and cost of MSDs in Turkey. Studies on protection and ergonomics training and the effectiveness of ergonomic interventions are inadequate. In the Labor Law No. 4857, the Regulation on Manual Carriage Works, the Regulation on Health and Safety in Work with Screened Vehicles and various other regulations, the employer has been obliged to identify and prevent musculoskeletal risks in workplaces, to provide employee protection and ergonomics training and to implement ergonomic improvements in the workplace. Considering the insufficiency of studies on the protection of musculoskeletal diseases and ergonomics in Turkey, Istanbul University Faculty of Medicine, Department of Physical Medicine and Rehabilitation established Musculoskeletal Diseases and Ergonomics Unit (Özcan, 2007).

1.2 Risk Factors in Occupational Musculoskeletal Disorders

Risk assessment is the most important phase of occupational health and safety activities. It addresses the risks involved in the activities performed in the workplaces and provides managers with appropriate information for taking measures. Despite the importance of risk assessment and the national and international regulations, a standard methodology could not be developed. Businesses perform this activity with the appropriate approaches. As a result, businesses generally use simple methodologies that are not sufficient to emphasize the main points of existing risks in the field of study and to effectively classify dangerous activities.

Occupational health and safety is the most important risk analysis activity of the organizations that want to carry out their activities in a systematic way. Risk analysis is the study of the determination of the hazards for the health of the workers in the working environment and determination of the probability of the occurrence and severity of the effect. All activities to be carried out for occupational health and safety and the measures to be taken should be planned by starting from the high level risks. At this point, it is very important to correctly calculate the risk value.

Otherwise, the significant risks are treated as relatively unimportant due to the incorrect scoring, and consequently high costs can be incurred. This may result significant loss in businesses.

One of the biggest pitfalls in calculating the risk value is the use of limited number of parameters. This may cause the calculation of same level of risks for different risk factors. By increasing the number of parameters and keeping the range of values necessarily wide, the values of the risks will better correspond to the real situation (Bıyıklı, 2011).

Musculoskeletal disorders, which may be accompanied by pain, movement restriction and injury due to exposure to physical and psychosocial risks during work activities, are common health problems of employees. It usually affects soft tissues such as muscles, tendons, ligaments, and discs. In the progress of these diseases, repetitive, forced movements in the workplace, the use of the body in bad positions and ergonomic deficiencies play an important role.

In recent years, the dramatic increase in the incidence and cost of MSDs in industrialized countries have attracted the attention of the employees, employer, government, health care systems and insurance companies, and studies on ergonomics programs and rehabilitation approaches, including risk factors, ergonomics training and ergonomic initiatives have accelerated.

Awareness of society on protection and ergonomics has emerged and training and initiatives on ergonomics have been rapidly spreading in the workplace. In Turkey, MSDs is recognized as an occupational disease by laws. The studies on the risk factors, working day loss, insurance compensation, cost, and protection training and the effectiveness of ergonomic interventions are insufficient.

According to Labor Law No. 4857 and the regulations on occupational health and safety, the employers are obliged to determine risks for prevention, and provide employee protection, and ergonomics training and ergonomic initiatives at work.

Features of MSDs can be stated as follows.

- They take first place among the causes of disability, working day loss and disease-related early retirement.
- Causes and effects are multifactorial.
- They are among the highest costs due to work day loss and insurance claims.
- Protection is generally possible (Özcan, 2007).

The role of physical and psychosocial factors related to work has been scientifically proven in the formation of MSDs. Factors other than business activities also participate in the formation of these diseases.

In 2001, The National Academy of Sciences in the United States reports that there is scientific evidence that musculoskeletal disorders in the lower and upper extremities may be linked to working conditions such as weight lifting, repetitive and forced movements, and stressful work environments, and that the problem can be alleviated by well-designed ergonomic intervention programs. The factors can be divided into business related and personal related risk factors.

1.2.1 Business Related Risk Factors

Business related risk factors are physical and ergonomic factors, and psychosocial factors.

1.2.1.1 Physical and Ergonomic Factors

Physical and Ergonomic Factors can be stated as in the following.

- Repetitive movements,
- Forced movements,
- Use of the waist and body in bad and wrong positions. For example, bending the knees forward without leaning forward, lifting the weight, using the computer in the formation of the carpal tunnel, and use of the wrist is an important factor.
- Same long-term position,

- Vibration.

1.2.1.2 Psychosocial Factors

In recent years, it has been shown that psychosocial factors play a role in musculoskeletal disorders.

- Job dissatisfaction,
- Monotone work,
- Time pressure,
- Insufficient supervisor and colleague support,
- Insufficient organizational factors such as lack of adequate rest breaks.

1.2.2 Personal Risk Factors

Personal risk factors can be stated as follows.

- Aging
- Inadequate fitness
- Cigarette
- Excess weight.

1.2.3 Who is at Risk?

Although there are risk factors for MSDs in every job and work, some jobs have a higher risk for some diseases. For low back pain, those who work in the industry with physical activity, heavy jobs, neck and upper extremity diseases with repeated movements in the industry and computer users are at high risk.

1.2.4 Efficiency and Protection of Ergonomic Conditions

It has been shown that ergonomics training and improvements are effective in decreasing the frequency and cost of MSDs and improving work efficiency, satisfaction, quality of life and return on investment. In long-term follow-up studies, cost of medical expenses, working day loss, insurance compensation payments and return to work were proven. It has been reported in a study that as a result of the implementation of comprehensive protection initiatives in various branches in the industry, the employers have saved between $80 and $2220 for each dollar spent on protection.

The main components of an ergonomics program are:

- Assessment of workplace risk factors
- Training
- Ergonomic initiatives

1.2.5 Evaluation of Risk Factors for Musculoskeletal Disorders at Work

The evaluation encompasses the following factors.

- Suitability of the equipment used in the work station to the employees
- Body positions during work
- Frequency and duration of repetitive activities
- Unusual activities
- Environmental factors such as vibration, heating, and ventilation (Özcan, 2007& Kesiktaş, 2007).

Training

The aim of the training of the employees and the ergonomics team is to develop appropriate and safe business behaviors and to create ergonomics awareness. Scope of the training is as follows.

- Musculoskeletal diseases, risk factors, early diagnosis and treatment
- Protection and ergonomics
- The use of proper body mechanics
- Ergonomic risks and solutions
- Exercises and physical activity
- Healthy lifestyle development.

Ergonomic Improvements

- Adapting the workstation, equipment and working conditions to the employee

- Administrative changes such as job modification, business planning, work organization, breaks.

1.2.6 Risk Assessment and Recommendations for Preventing Injuries

1.2.6.1 Features of Load

Characteristics of the load may include a risk of a back injury, in particular:

- If it's too heavy or big
- If it's bulky or cannot be handled
- If it is unstable or likely to play
- If it is positioned in such a way that it must be held or moved away from the rear trunk, or if the baggage requires twisting or curling.

1.2.6.2 Working Environment

The work environment can increase the risk especially in the following cases.

- If there is not sufficient space to perform the activity
- If the ground is not stable, causing a fall and slip hazard
- If the work environment prevents the loads from being transported at a safe height and with good posture
- If there are differences on the floor
- If the floor or footrest is unstable
- If temperature, humidity or ventilation is inappropriate.

1.2.6.3 Activity Requirements

If the activity requirements include one or more of the following, it may include the risk of a back injury in particular.

- Excessive or prolonged physical effort, especially in the spine
- Poor body resting or recovery time
- Excessive lifting, lowering or carrying distances

- The rate of work imposed by a process that cannot be changed by workers.

If proper posture and body mechanics have complied, 99% of the workforce can carry loads up to 10 kg (22 lbs) without risk. This value should be used as the general reference mass in the risk assessment.

1.3 Working Positions

Posture is the state of the body that the operators must adopt or take during work activity:

- Seating
- High seating
- Assisted standing
- Standing

The load is the mass of parts that are lifted, moved or positioned. Structure of the workstation affect the load.

- Workstation with high seating is a workstation that allows the operator to sit and stand at the same time
- Workstation with assisted standing is a workstation with an assisted standing seat that supports up to 60% of the operator's weight.

Reducing the height of the thresholds on the conveyor edges can reduce the congestion in front of the luggage compartment. Accordingly, MSDs due to prolonged and repetitive leaning to forward can be avoided. The proper distance of reach is illustrated in Figure 1.1.

Figure 1.1 The proper distance of reach to avoid MSDs due to prolonged and repetitive leaning (Schneider Electric Magazine, 2014)

- Standing positions must be preferred over sitting or high sitting positions. If the business process allows, assistive standing must be preferred.
- Going back and forth between sitting or high sitting and standing allows static muscle fatigue to be eliminated. In this case, a high-sitting workstation must be designed.
- Seated and elevated seated workplaces reduce fatigue and facilitate the operation of operators of different weight and length. Seated posture makes body movements more accurate.
- It is recommended to use floor mats for standstill operation.
- Posture restrictions are related to the equipment and person's height-weight characteristics.

All motionless postures soon become painful, therefore, when you feel the need to change the position you should change it.

Posture is the first factor to be determined, and other workstation factors should be determined accordingly. The most common challenge is the work posture determined in the workstation design.

It is important that the two-hand area is centered at an average distance of 200 mm (8") from the table edge (150-250 mm-6" to 10") when performing assembly that requires body movement and precision.

For workstations with seats that are sitting or high-sitting, the areas that are defined as half-circles become linear for standing workstations and the operator can move in front of the workstation.

1.3.1 Seating Work and Chair Design

If there is not sufficient working space, and a few number of physical activity is required during a job, that job can be done by sitting. Working all day sitting is not good for the body, especially for the back. For this reason, employees should have the opportunity to work standing up by changing their positions. A well-selected chair for sitting is a must. The chair should be able to easily adjustable to the leg and the general position of the worker.

The following are the ergonomic rules that must be observed during sitting:

- Workers should be able to reach all areas easily and should not bend.
- The good sitting position is that the worker is upright against the work area that is in front and next of him/her.
- The desk and chair should be well designed and the working level and the elbow should be in the same plane (same height).
- The back should be upright and shoulders should be relaxed.
- If possible, use adjustable supports for the elbows, hands, and arms.

1.3.1.1 Work Chair

Chair selection should be made with the following factors.

- Task restrictions
- Posture flexibility
- Ease of sitting and standing
- Required chair stability
- Upholstery material
- Ease of adjustment.

The lightness and compactness of the seat simplify the implementation of the lean manufacturing principles (workstation replacement and mutual assistance).

1.3.1.2 Seated and High Seated Positions

- The working chair should be easily adaptable to the specific needs of each user.
- The seat section must provide support and should not pressurize the back of the leg.
- The material used must prevent sweat accumulation and electrostatic discharge.
- The height and inclination of the adjustable backrest should allow the back muscles to relax.
- In order to maintain stability, the base of the seat must have 5 support points. It is recommended not to use a swivel chair wheels for a high sitting position. They may cause a risk when the chair is moved.
- The adjustment devices for adapting the seat to the job situation should be easy to handle and reliable.
- Correct adjustment of the seat requires the operator to be notified of the current risks.

1.3.1.2.1 Choice of Footrest. The footrest cannot be used during chair use. It can only be used in sitting or high sitting positions.

- The transport surface must be non-slip.
- Height adjustment due to individual height-weight differences is compulsory.
- For workstations with foot control, it is wise to integrate these controls to the foot in order to achieve an overall height adjustment.
- The footrest must be mounted in the workstation or adhered to the floor sufficiently.
- The chairs used on the high sitting workstation can be equipped with a footrest that allows the operator to change his / her position.

The footrest is a necessary apparatus for a high seated workstation and the desired apparatus for a seated workstation to provide support to the legs. Figure 1.2

illustrates the dimensions that should be observed for chair positions for high-seating and seating workstations.

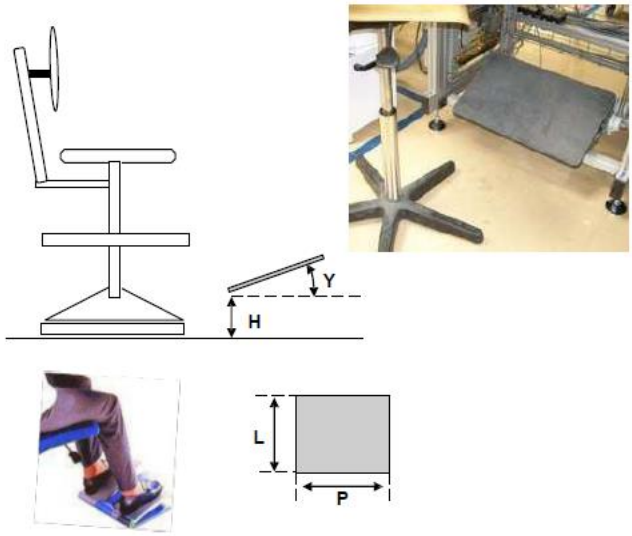


Figure 1.2 Chairs for high seated and seated workstations (Schneider Electric Magazine, 2014)

1.3.2 Supported Standing Positions

Only workstations where a permanent sitting position or sitting and standing positions cannot be used in combination should be used with a seat with assist chair.

The advantages of a seat with assist include:

- Supports up to 60% of body weight
- Facilitates transition to the standing position.

The disadvantages of the seat with assist are:

- Pressure and limited blood circulation to a specific area
- Legs tend to swell after a short time
- Working positions are restricted.

When the work to be done is within reach of the elongated arm, there must be sufficient space for the knees and legs. When this gap is not achieved, the reach of the arm is shorter than in the normal standing position.

Seat with an assist

- The seat should be in the form of a seat or the seat section should be tilted forward and its depth shall be relatively shallow
- It should be easily adjustable
- It should be light to be easily replaced
- Instead of choosing a standing position, it is a better option to use a seat with an assist.

Figure 1.3 Workplace design (Schneider Electric Magazine, 2014)

Consideration of the rules of ergonomics when designing workplaces improves the working conditions and the efficiency of the activities of the employees. Figure 1.3 presents two examples of workplaces.

Jobs requiring precision include a high visual load (visual distance in the 30 cm to 12" step), with clear positioning and a millimeter degree of clarity, which appears in at least 30% of the cycle time. Load lifting is one of the subjects that require precision in case of standing operation. Figure 1.4 illustrates examples of load-bearing stance.

Figure 1.4 Work and work postures (Schneider Electric Magazine, 2014)

1.3.3 Viewing Distance

It corresponds to the visual necessity of the task. The direction of view and the eye-to-task distance are defined. Visibility distances should not exceed 50 cm, and the distance can be reduced to 30 cm for small parts or motion sensitivity requirements.

Visibility is effective in case of proper character dimensions, and to ensure optimum readability, colors and contrast should be selected appropriately. The vision zones are defined in the following.

Main view axis: Product axis to be assembled with the eye

Visual comfort zone: The region around the main viewing axis. The view in this region can only be changed by moving the eyes.

Acceptable zone: A region in which vision requires small head movements to allow one to detect the component. This zone can be used when the comfort zone is insufficient.

Troublesome zone: The area to be used only under certain conditions (e.g. light signal accompanied by an acoustic signal). Large head movements are required to scan this area.

1.4 Material Handling Positions

The main risk factors for material handling positions can be stated as follows.

- Heavy and repetitive lifts
- Strong lifting and stressful operations
- Maintaining bending and bent postures while lifting
- Poor physical condition and fatigue.

Leaning and bending while lifting contains high risk. Figure 1.5 illustrates the incorrect postures and lines of transport.

Figure 1.5 Incorrect material handling postures (Schneider Electric Magazine, 2014)

In Figure 1.7, the weight loaded to the waist is 375 kg in wrong load lifting, and can be reduced to 75kg with the right lifting as in Figure 1.6.

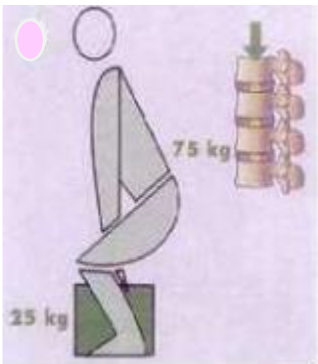


Figure 1.6 Incorrect load removal (Schneider Electric Magazine, 2014)

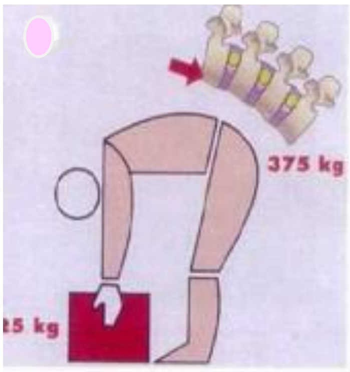


Figure 1.7 Lifting the right load (Schneider Electric Magazine, 2014)

1.5 Anthropometric Models

Anthropometry has found its application in the trade as well as its academic functions. Besides the products such as automobile seats, pilot cabinets, space capsules, anthropometric data are used in garment design, especially military uniforms.

Figure 1.8 presents the anthropometric measurements of a male of medium height.

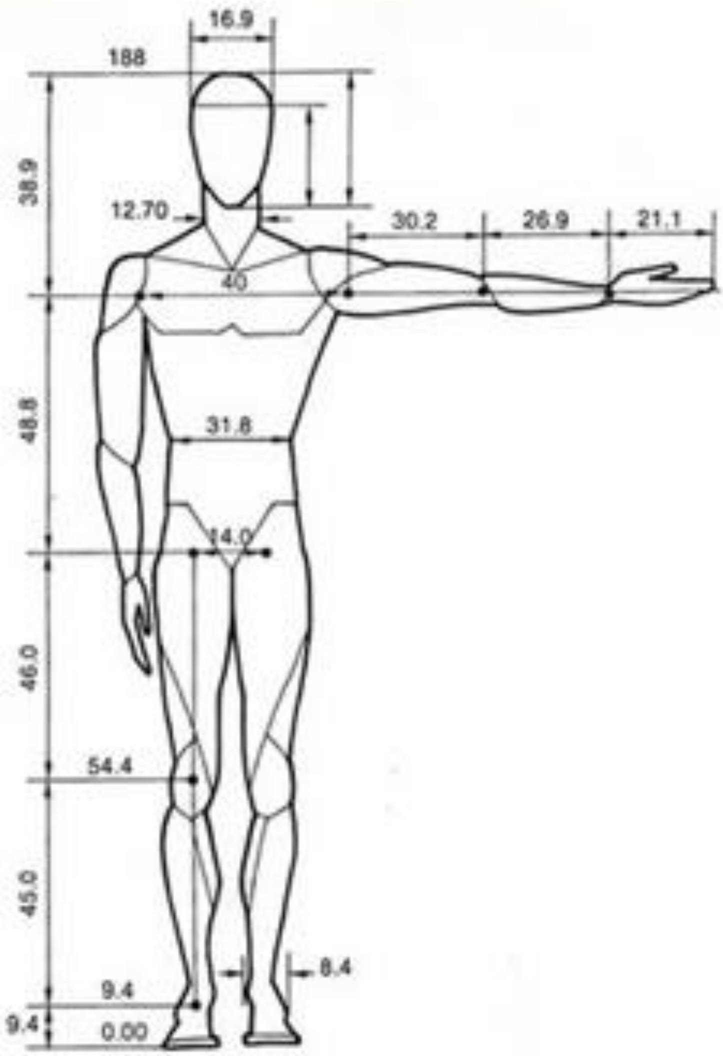


Figure 1.8 Medium-sized male anthropometric model (Nedenisguvenligi, 2018)

Figure 1.9 illustrates the anthropometric measurements of a medium-sized female.

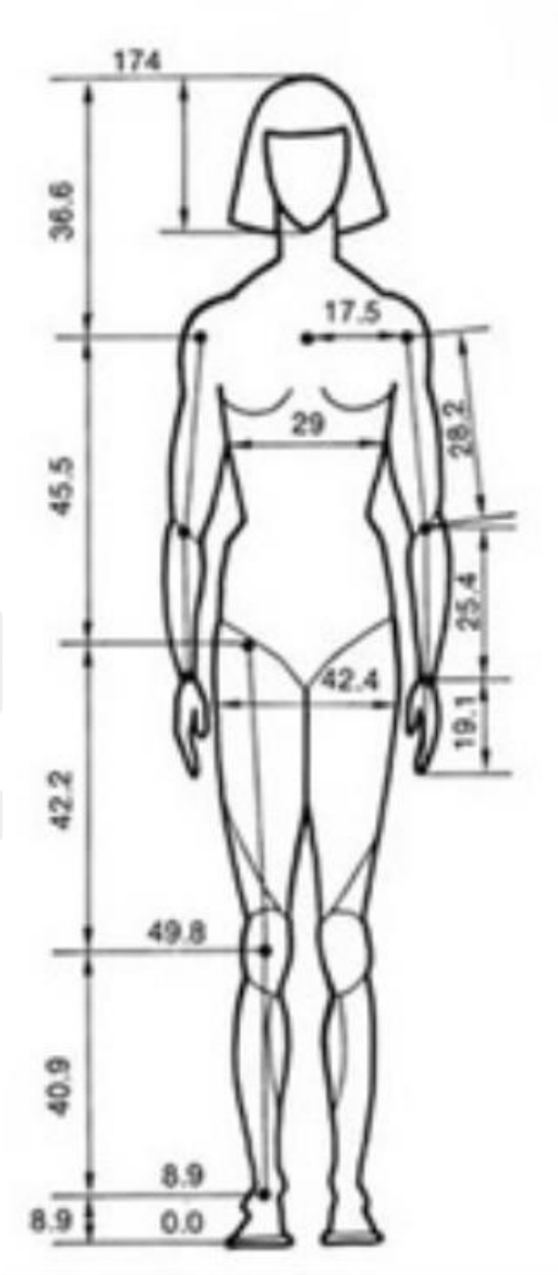


Figure 1.9 Medium-sized female anthropometric model (Nedenisguvenligi, 2018)

CHAPTER TWO
MATERIAL AND METHOD

There exists many observations and survey-based methods used to determine the risk levels and scores of positions to minimize the risks of occupational accidents and to determine the disturbances caused by incorrect stoppages. Some of the frequently employed methods are OWAS, RULA and REBA, which are described in the following subsections.

2.1 OWAS

OWAS (Ovako Working Position Analysis System) is an observational position analysis method which is used to determine the loading of the musculoskeletal system and the bad positions caused by the system. It is designed as an analysis tool to serve the business surveyors and is a time-based job sampling tool. In this method, the photographs of those who work in heavy industry during the study were taken and expressed schematically. The work positions were standardized and applied to industry as “OWAS Working Positions”. OWAS allows the detection of poor positions and activities, the comparison of different systems according to the power that the workforce spends, and estimation of the most suitable work methods. In addition, it enables the workplace to be evaluated in terms of efficiency, comfort and occupational health and systematic examination of the human machine interface. The positions are classified in this method and systematic studies are carried out in order to eliminate the disturbing elements (Akay, 2003).

In the analysis by OWAS, WinOWAS software developed in Tampere Technical University of Finland can be used. The data is entered into the sofware using the coding sequence and the software analyzes the defined stop. As a result of the analysis, the risk level of the movement is obtained. Figure 2.1 presents WinOWAS data entry and Figure 2.2 presents an example of the analysis results.

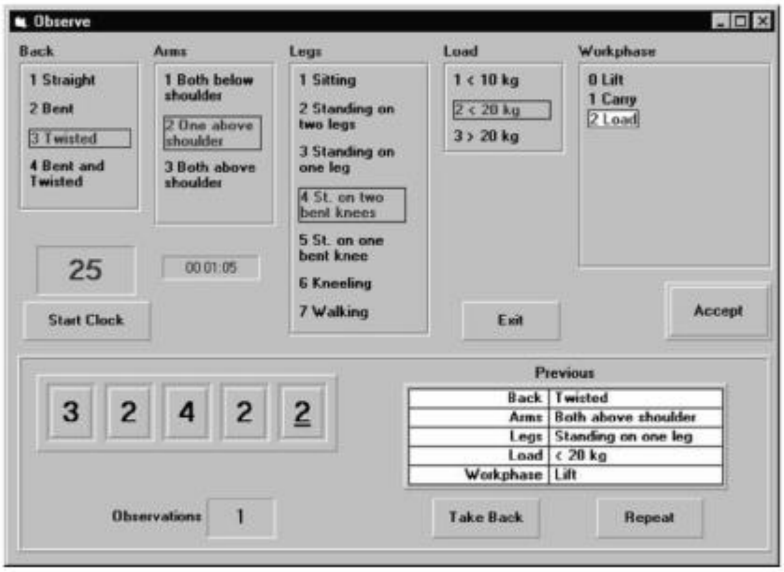


Figure 2.1 WinOWAS data entry window (Kocabaş, 2009)

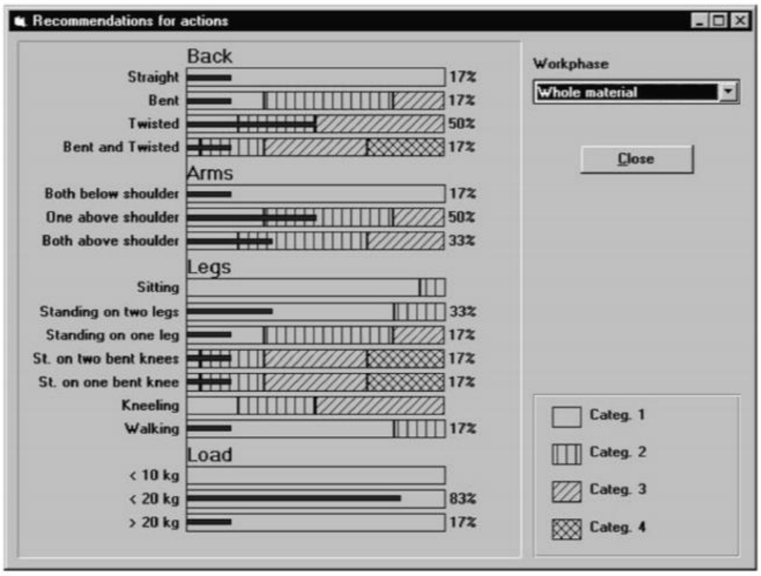


Figure 2.2 Graphical representation of posture analysis (Kocabaş, 2009)

2.2 RULA

RULA (Rapid Upper Limb Assessment) is a method developed to evaluate the load on the muscle-skeletal systems of the employees due to their position, muscle function and strength. This method is designed to assess the employees who are exposed to musculoskeletal loads that cause upper limb (hand-wrist-elbow-lower arm-upper arm-shoulder-neck) disturbances. In the RULA method, there is a scoring system that allows the body regions to specify the load levels they are exposed to. This method reliably performs the evaluation of working positions, as in the OWAS method, without any additional equipment. According to the method, the predefined classifications of upper body, neck, back and leg position and their numerical values are used to determine the risk score of the observed positions (Vasconcellos, 1988).

RULA is an observational tool that evaluates postural and biomechanical loading on the whole body, while paying particular attention to the neck, body and upper limbs. It is convenient to use RULA method in simple and repetitive tasks. This method can be successfully applied to jobs in the healthcare industry (nursing, repair, cashier services, telephone operators, ultrasound technicians, dentists etc.) (Erensal, 2009).

The basis for the assessment scores consists of the section A for the arms and wrists, and the body B for the body and the neck. There are additional adjustments to be considered for the planning scale and score for each region. Hand, arm, wrist and foot drawings of RULA are the same as the REBA method, which will be the score of the body positions. The different parts and tables A, B and C are described, and the application is made with the default positions.

In this thesis, REBA method is employed, and an ergonomic risk assessment is performed in a manufacturing firm. The method is introduced in the following section.

2.3 REBA

REBA is a useful tool for calculating the risks involved in manual handling and lifting operations. It was developed by Hignett and McAtamney (2000) to analyze stances. It combines body positions in structure and load quantities in a quantitative sense. With the REBA method, dynamic movements and fixed stops can be analyzed. In some cases, it may be more appropriate to repeat the analysis several times for a single movement. The total risk caused by the desired position or movement to be analyzed using REBA can be expressed numerically. The ability to express the risk numerically is used to indicate the risks and dangers of the individual movements and positions in the analyzed stand. Each movement or position indicated is divided into angles for the upper and lower body.

The total score is calculated by the combination of the positions of the neck, the trunk and the lower and upper limbs. Other factors in the REBA method include the degree of convenience of the load to be lifted, the grip on the load, how often the movement is performed, whether the body is stationary during movement or whether there is rotation or twisting when moving (Kocabaş, 2009).

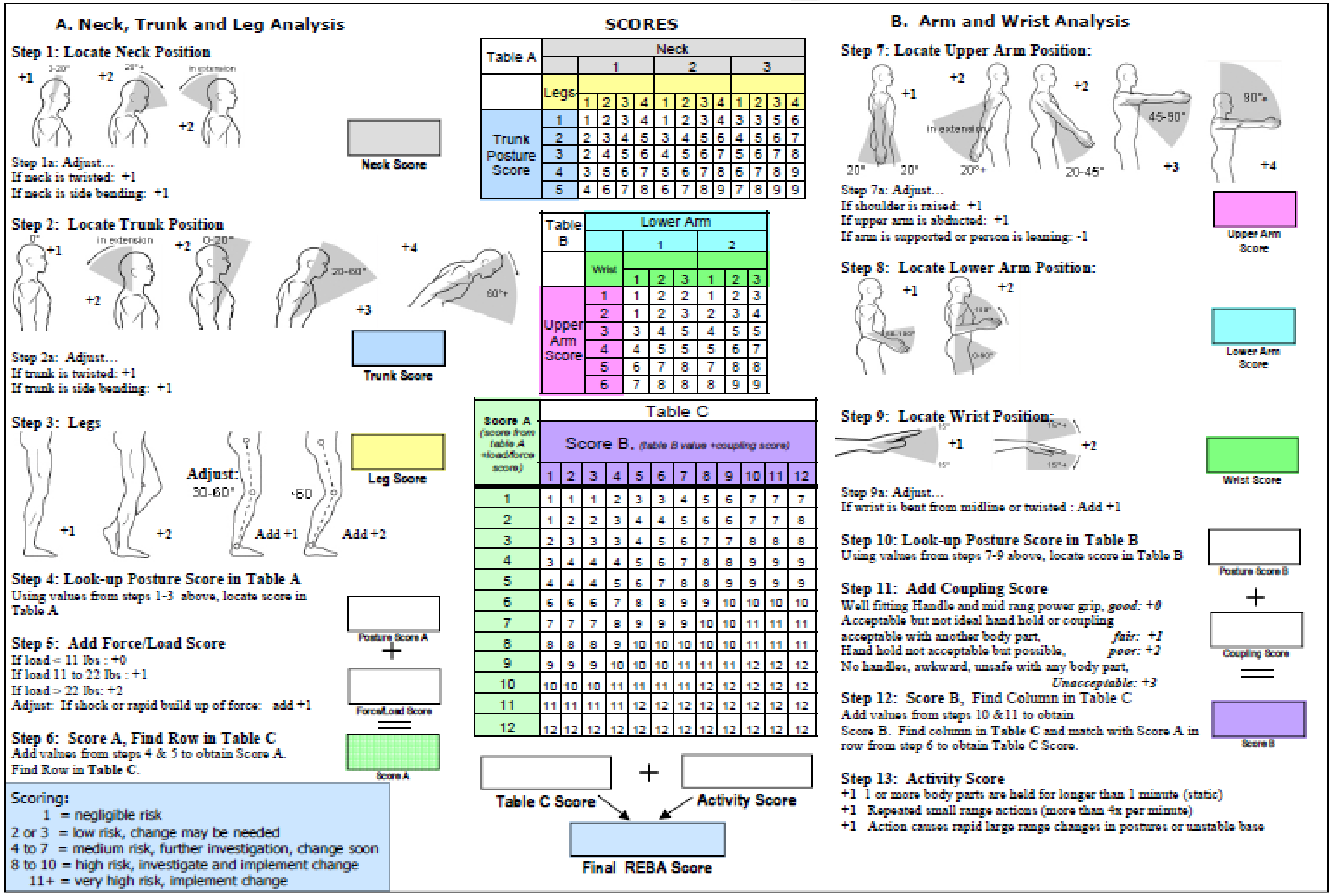


Figure 2.3 The algorithm for determining the REBA score (Middlesworth, 2017)

The legs, torso and neck positions are shown in Table A in Table 2,3; and upper arm, lower arm and wrist stance are scored according to Table B. The load / force relationship is added respectively to these scores. The Score A and Score B are combined in Table C and the score C is found. The predetermined score is added to Score C and total postural score is found. Figure 2.3 is a schematic representation of the REBA score calculation.

CHAPTER THREE
THE APPLICATION

This study aims to examine the risk factors of MSDs associated with different work postures of the employees in an international manufacturing firm by using ergonomic evaluation criteria. To this aim, the risky production divisions of the firm are determined by a survey firstly. Then, risk levels of the tasks for the selected production divisions are measured by using REBA method. More specifically, 20 employees working in the F400 section of the firm, which is observed to be the most challenging and risky section, were investigated about musculoskeletal disorders. Accordingly, the videos of the employees were recorded during the shifts, then the videos were analyzed and the risky tasks were identified. The employees and observation time were selected randomly during the shifts.

3.1 The Survey

In the firm, incorrect postures causing musculoskeletal disorders were examined by observations and video analysis. Whether the disturbances experienced in the risky sections occurred during the working period was investigated by the survey conducted in these regions.

Table 3.1 reports that only two of the workers under concern are female.

Table 3.1 Genders of employees

Male	Female
18	2

Table 3.2 presents the distribution of the employees participating in the survey by age categories. Figure 3.1 illustrates that 30% of the employees are between the ages of 31-35 and 36-40. In addition, 25% of them are over the age of 40.

Table 3.2 Distribution of employees by age categories

Age	Count
20-25	1
26-30	2
31-35	6
36-40	6
40+	5

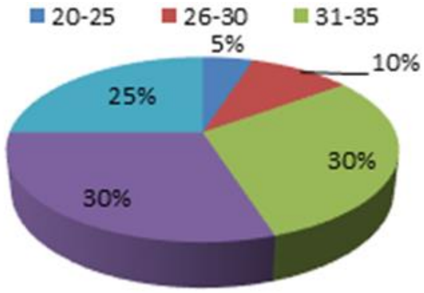


Figure 3.1 Age groups of the employees

Table 3.3 Distribution of the employees to the departments

Department	*Count*
Topay Front Assembly	1
Busing Assembly	2
Right-Left Side Sheet Assembly	2
Loc	1
Plate	1
Topay Box Front Assembly	1
Rotary Transformer	1
Rotary Transformer Wiring	2
Cable Kit-Heater Kit Preparation	1
Current Transformer Mechanical Assembly	1
Current Transformer Wiring	1
Cabling Compartment Busbar Assembly	2
Cable Compartment Base Plate Heater Assembly Cell	2
Busing Transformer Wiring	1
AG Cabinet Hanging	2
Door Assembly	1
Roof Assembly	1

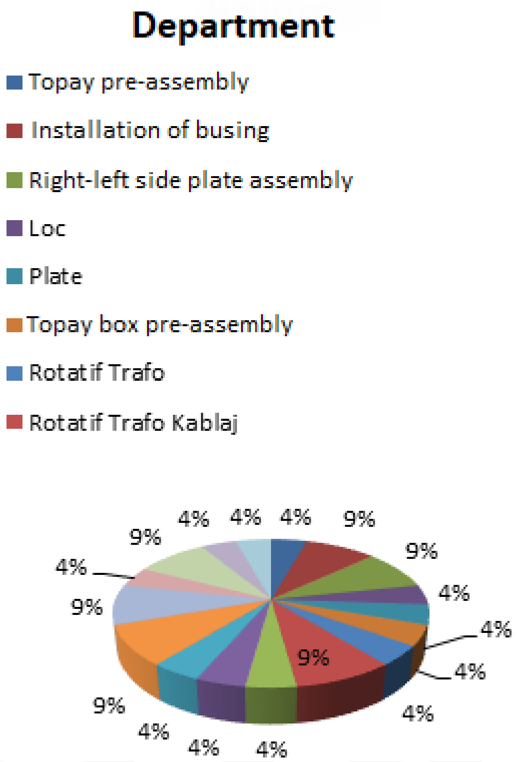


Figure 3.2 Distribution of the employees to the departments

Table 3.4 reports employee satisfaction levels from the working conditions. The Table reveal that almost all of the workers are pleased with the height of the workbench, and most of them are pleased with the working area and equipment placement. However, almost all of the workers are not satisfied with the weight of work tools, and only 6 of them are pleased with the break time. Figures 3.3 and 3.4 illustrate graphically the satisfaction levels from the working conditions.

Table 3.4 Employee satisfaction levels from the working conditions

	Working Area	Equipment Placement	Bench Height	Weight of Work Tools	Break Time
Yes	16	16	19	1	6
No	4	4	1	19	14

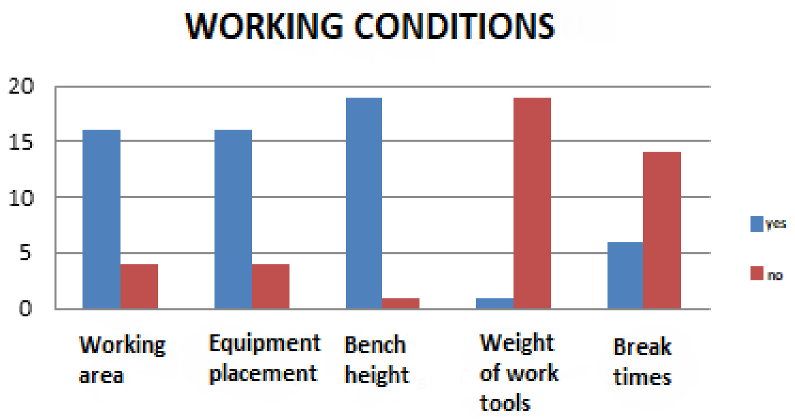


Figure 3.3 Bar chart of the satisfaction levels from the working conditions

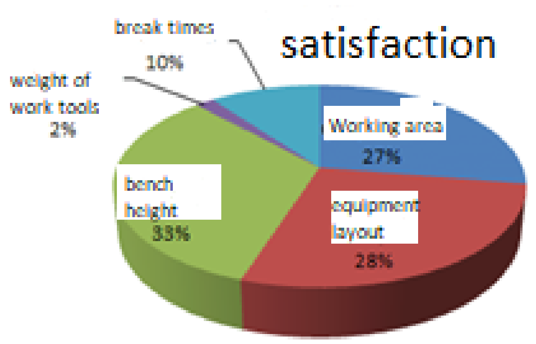


Figure 3.4 Pie chart of the satisfaction levels from the working conditions

Table 3.5, and Figs. 3.5 and 3.6 present distribution of employees' musculoskeletal disorders. The observations reveal that the most common complaint is waist (low back) pain. Seven employees suffer from low back pain, four of which severely suffer. In addition, six employees complain neck pain, three of which severely suffer.

Table 3.5 Distribution of employees' musculoskeletal disorders

	Musculoskeletal disorders								
Severity Level	*Ankle*	*Knee*	*Waist*	*Back*	*Wrist*	*Front Arm*	*Elbow*	*Shoulder*	*Neck*
1 (low)	1	0	1	1	0	0	0	0	0
2	0	0	1	0	0	0	0	0	0
3	1	1	1	1	0	0	1	0	2
4	0	1	0	0	0	0	0	2	1
5 (high)	1	0	4	1	1	1	1	1	3

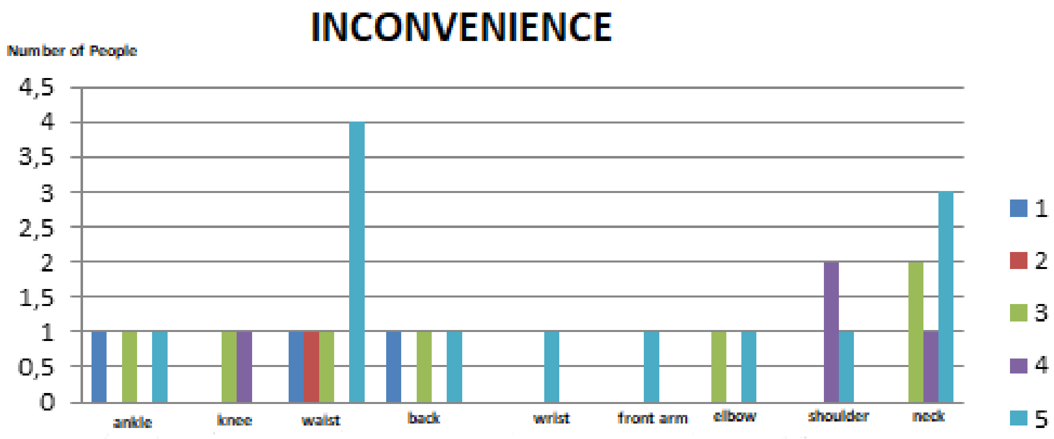


Figure 3.5 Bar chart of the distribution of employees' musculoskeletal disorders

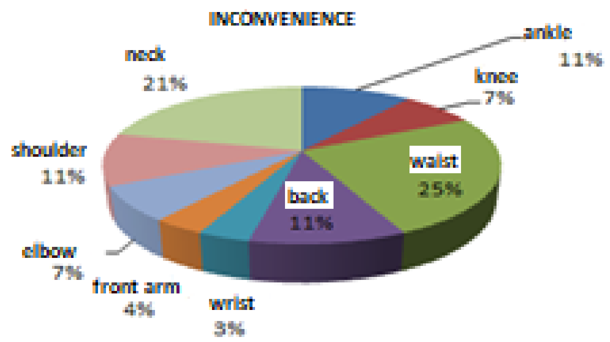


Figure 3.6 Pie chart of the distribution of employees' musculoskeletal disorders

Table 3.6. and Figure 3.7 report the distribution of the frequency of applying to the doctor due to musculoskeletal disorders. As stated, 14 of 20 workers apply doctors because of their disturbance. The frequency of applying to doctor once a year has the highest value, 40%. Two of the 20 employees apply doctor 10 times or more in a year. It is investigated whether or not these employees are working on the proper working conditions in the subsequent section of the study.

Table 3.6 Distribution of the frequency of applying to the doctor

Doctor	Count
0	6
1	8
2-10	4
10+	2

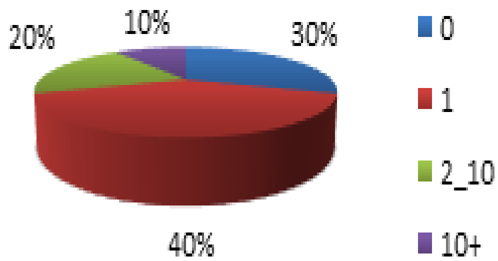


Figure 3.7 Distribution of the frequency of applying to the doctor

3.2 REBA Application

As stated previously, the most risky production division of the firm are determined by the survey. Then, risk levels of the tasks for the selected production division are measured by using REBA method.

3.2.1 Topay Assembly Section

In Topay assembly section of the company, Topay pre-assembly, busing assembly, ball-box pre-assembly, loc and plate operations are performed. The department employs 8 workers and each worker is doing different jobs.

As illustrated in Figure 3.8, the REBA score for the busing assembly is 8. Herein, the worker is tilting forwards by 20 degrees, bending the upper arm more than 45 degrees and bending his lower arm more than 100 degrees and bending his wrists by 15 degrees. If there is a need to change the working position of the employee, a platform should be established to prevent him from lean forward. In addition to these changes, stance training should be given about during the work.

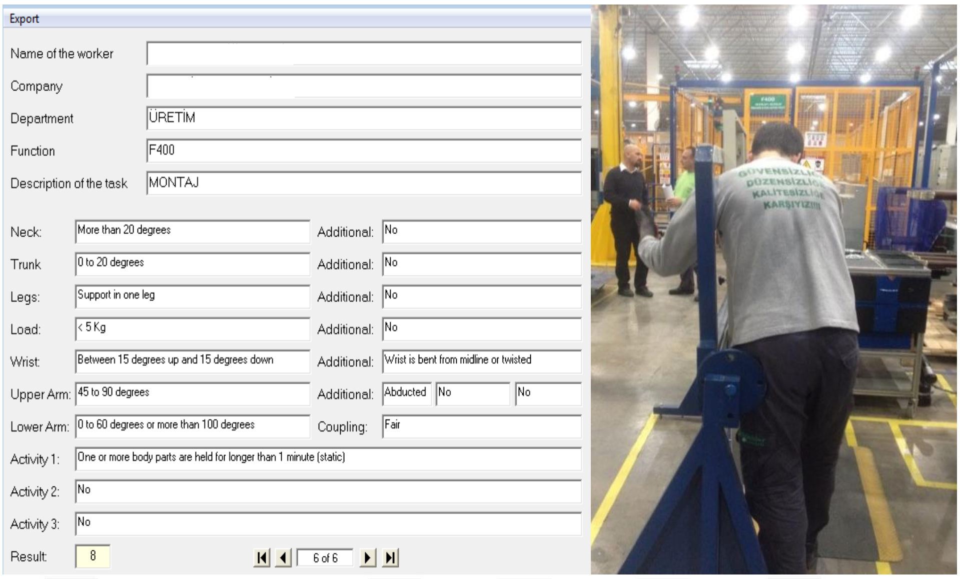


Figure 3.8 Topay assembly section REBA score-1 (Personal archive, 2019)

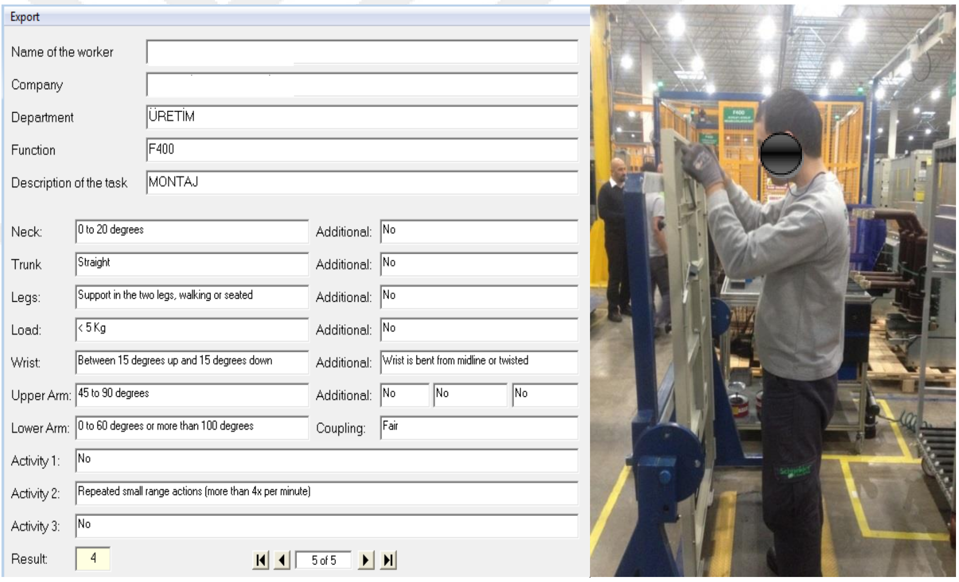


Figure 3.9 Topay assembly section REBA score-2 (Personal archive, 2019)

As illustrated in Figure 3.9, the REBA score for the busing assembly is 4. Herein, the montage worker is tilting his neck 20 degrees forward, bending his upper arm more than 45 degrees, bending his lower arm more than 100 degrees and bending his wrists by 15 degrees. A step or platform should be designed to prevent the employee from reaching out if his work position needs to be changed. If there is a need to change the working position of the employee, a platform should be established to prevent him from lean forward. In addition to these changes, stance training should be given during the work.

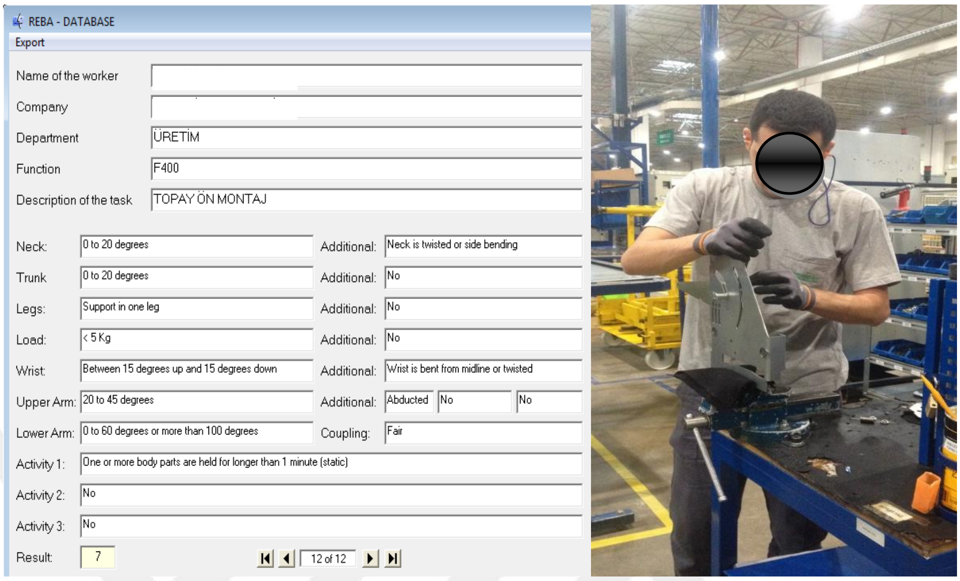


Figure 3.10 Topay assembly section REBA score-3 (Personal archive, 2019)

As illustrated in Figure 3.10, the REBA score rises to 7 as a result of tilting of the neck of Topay pre-assembly worker at 20 degrees forwards, bending his body forward 20 degrees, bending his upper arm more than 20 degrees, bending his lower arm more than 60 degrees and bending his wrists 15 degrees. A change in the working position of the employee is required. These changes should be discussed at an improvement meeting with the employer, which may include redesign of the workshop.

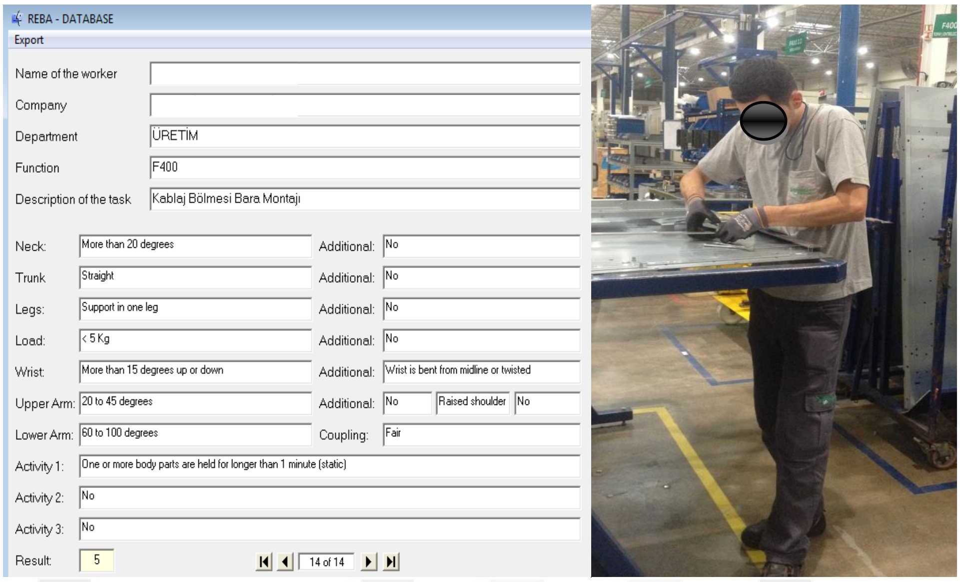


Figure 3.11 Topay assembly section REBA score-4 (Personal archive, 2019)

As reported in Figure 3.11, the REBA score is 5 due to the fact that the montage worker in the production line tilted his fore arm more than 20 degrees forward, bending his upper arm more than 20 degrees, bending his lower arm more than 60 degrees and bending his wrists more than 15 degrees. A change in the working position of the employee is required.

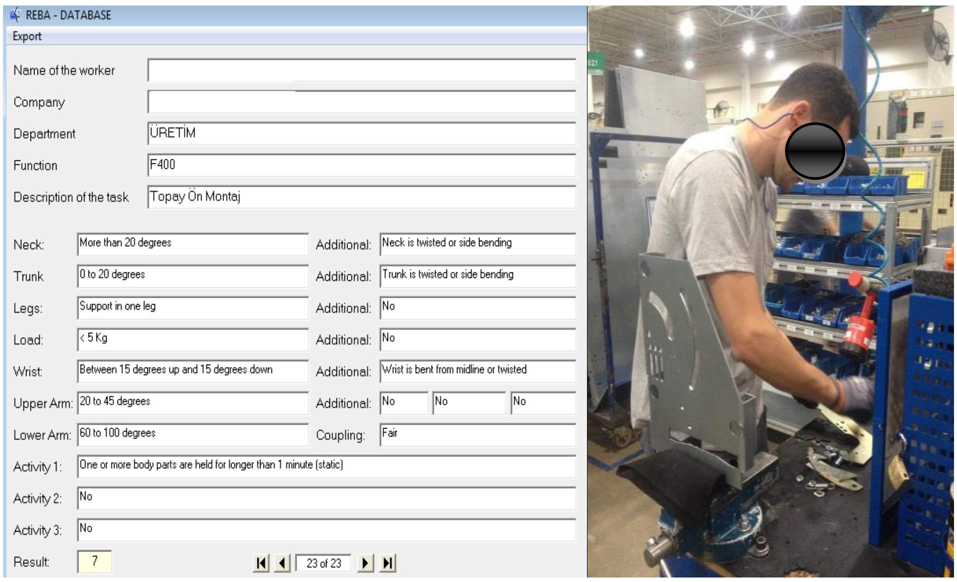


Figure 3.12 Topay assembly section REBA score-5 (Personal archive, 2019)

As presented in Figure 3.12, the REBA score is 7 due to the fact the front of the pre-montage worker bends 20 degrees forward, bends his body 20 degrees forward, bends his upper arm more than 60 degrees, bends his lower arm between 20 and 45 degrees and bends his wrists more than 15 degrees. A change in the working position of the employee is required.

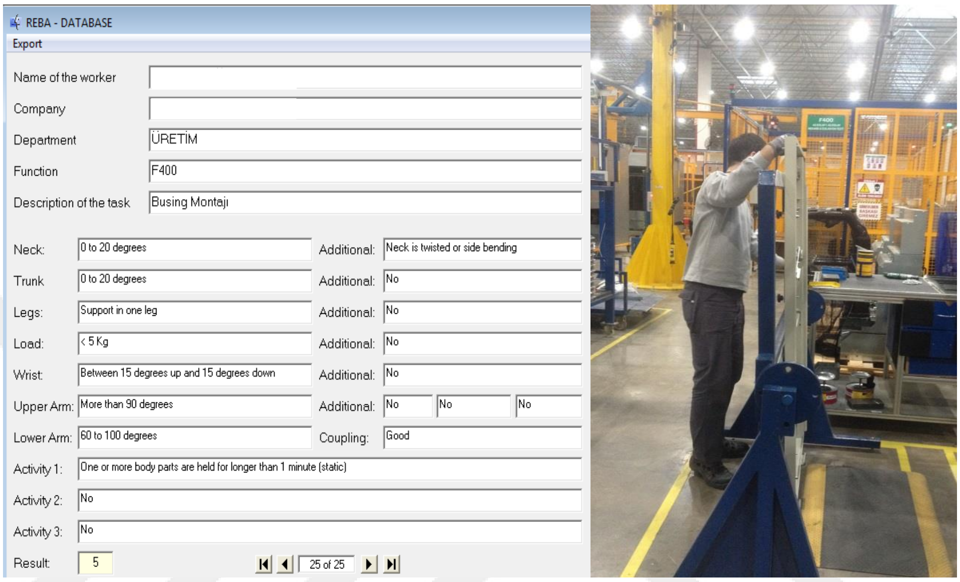


Figure 3.13 Topay assembly section REBA score-6 (Personal archive, 2019)

Figure 3.13 illustrates that the busing production line worker tilts his neck 20 degrees forward, tilt his body 20 degrees forward, tilt his upper arm more than 90 degrees, bend his lower arm more than 60 degrees and bend his wrists up and down more than 15 degrees. Therefore, REBA score takes the value of 5. This score can be reduced to a lower level with a posture training given to the employee.

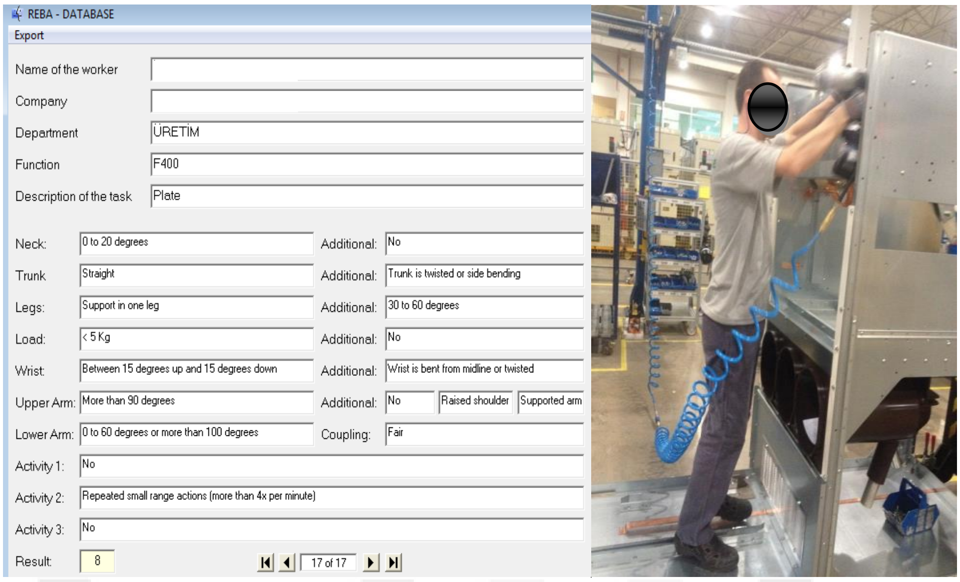


Figure 3.14 Topay assembly section REBA score-7 (Personal archive, 2019)

Figure 3.14 reports that the plate montage worker forward 20 degrees forward from the neck, bending his upper arm more than 90 degrees, bending his lower arm more than 60 degrees, bending his wrists more than 15 degrees upward and downward tilting and working by placing the single foot. Therefore, REBA score takes the value of 8. There is an urgent need to change the working position of the employee.

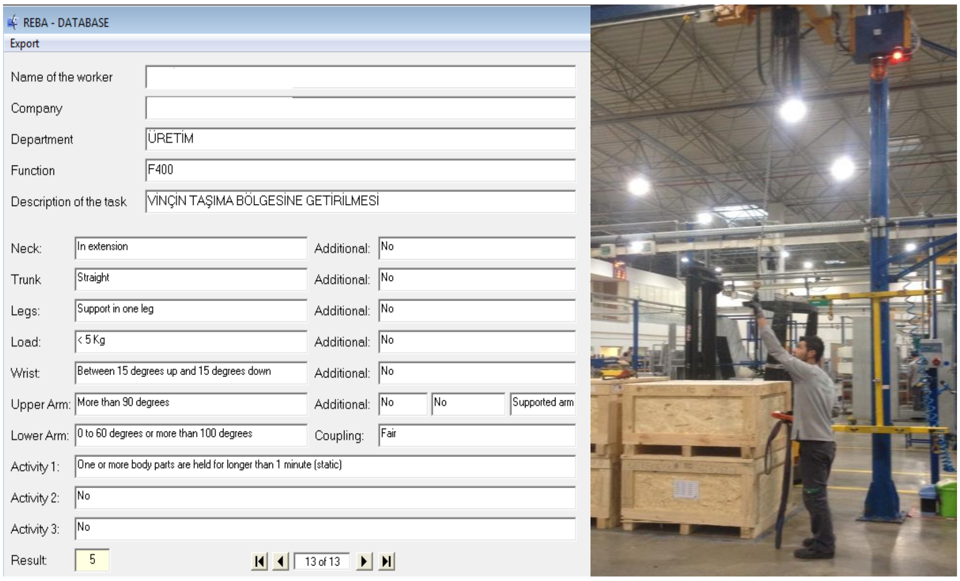


Figure 3.15 Topay assembly section REBA score-8 (Personal archive, 2019)

Figure 3.15 illustrates that the crane in the production line was moved to the transportation area. The neck of the worker stretched too far backward, he is bending his upper arm more than 90 degrees, bending his lower arm more than 60 degrees and bending his wrists 15 degrees upwards. Therefore, the REBA score takes the value of 5. It can be stated here that a change in the working position of the employee is required.

In the analysis carried out in Topay assembly section, 8 work postures are analyzed as reported in Table 3.7. Table 3.8 presents the age and disturbance distribution of employees of Topay Assembly Section. In general, postures are categorized as medium risk, with an average REBA score of 5.6. Topay employees' age and disturbance distributions are illustrated in Figs. 3.16 and 3.17. As reported in the Tables, 29% of the employees working in the Topay department are between 31-40 years of age. 25% of the disturbances are neck pain, while 17% of them are waist, ankle and shoulder pain. The results suggest that it should be tried primarily to eliminate the neck, waist, ankle and shoulder disturbances by giving training to the employees and redesigning the work or workshop.

Table 3.7 REBA analysis results of Topay Assembly Section

Department	*Work*	*REBA Score*	*Risk Level*
Topay Assembly	Busing production line	4	Medium
	Montage	4	Medium
	Kablaj compartment bara montage	7	Medium
	Transfer of boilers to production	5	Medium
	Topay pre-montage	7	Medium
	Busing production line	5	Medium
	Plate montage	8	High
	Bringing the crane to the transport area	5	Medium
Average REBA score		5.6	Medium

Table 3.8 Age and disturbance distribution of employees of Topay Assembly Section

	Age	*Number*	*Disturbance*	*Number*
Topay Assembly	20-25	1	Ankle	2
	26-30	1	Knee	1
	31-35	2	Waist	2
	36-40	2	Back	1
	40+	1	Wrist	0
			Fore Arm	0
			Elbow	1
			Shoulder	2
			Neck	3

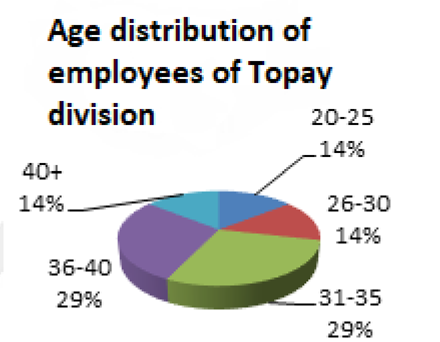


Figure 3.16 Topay employees' age distribution

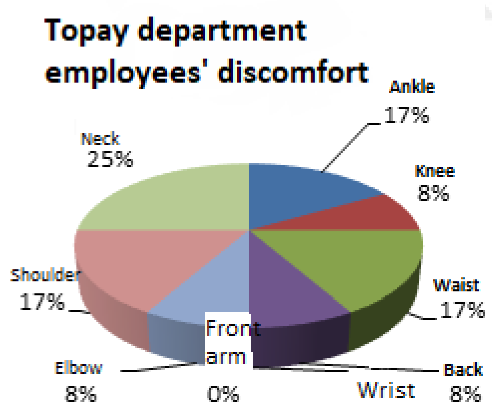
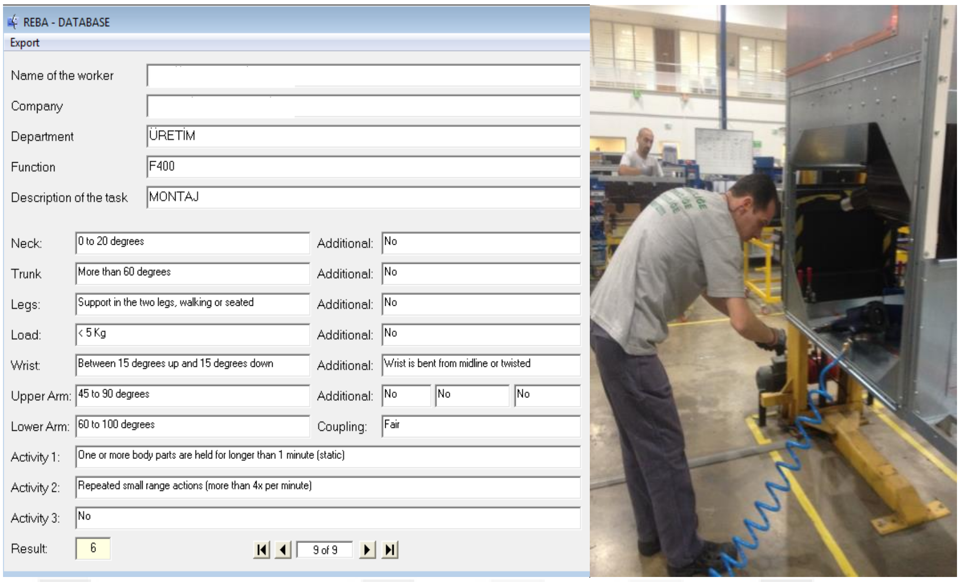


Figure 3.17 Topay employees' disturbance distribution

3.2.2 Rotary and Current Transformer Section

In the Cover Section of the firm, rotary transformation, rotary transformer cabling, cable kit-heater kit preparation, current transformer mechanical installation cell suspension, current transformer cabling operations are performed. REBA analysis is performed for 6 works in Rotary and Current Transformer Section.



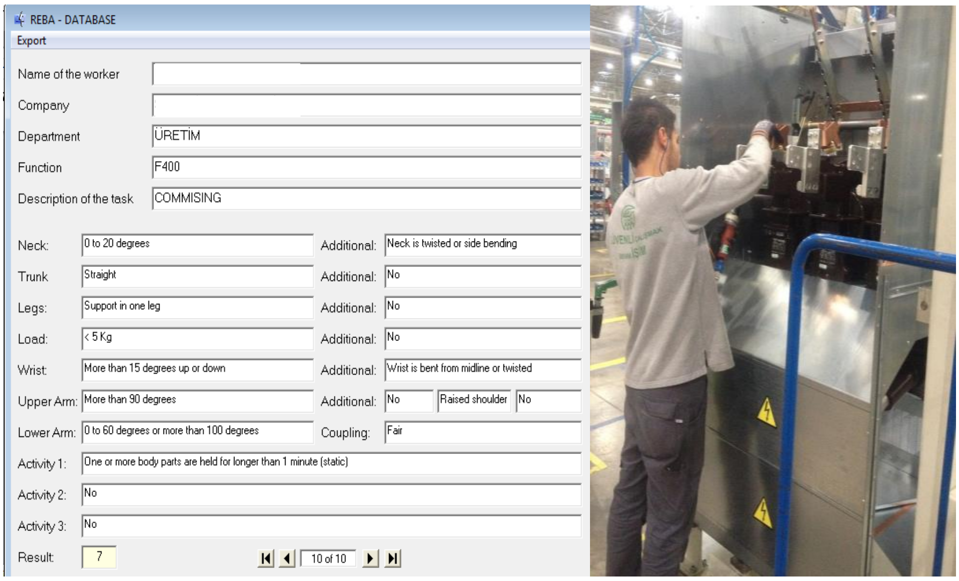
REBA - DATABASE
Export

Name of the worker	
Company	
Department	ÜRETİM
Function	F400
Description of the task	MONTAJ

Neck:	0 to 20 degrees	Additional:	No
Trunk:	More than 60 degrees	Additional:	No
Legs:	Support in the two legs, walking or seated	Additional:	No
Load:	< 5 Kg	Additional:	No
Wrist:	Between 15 degrees up and 15 degrees down	Additional:	Wrist is bent from midline or twisted
Upper Arm:	45 to 90 degrees	Additional:	No / No / No
Lower Arm:	60 to 100 degrees	Coupling:	Fair
Activity 1:	One or more body parts are held for longer than 1 minute (static)		
Activity 2:	Repeated small range actions (more than 4x per minute)		
Activity 3:	No		
Result:	6		9 of 9

Figure 3.18 Rotary and Current Transformer Section REBA score-1 (Personal archive, 2019)

Figure 3.18 states that REBA score is 6 as a result of the installation worker tilting his neck 20 degrees forward, bending his body forward more than 60 degrees, bending his upper arm more than 45 degrees and bending his lower arm more than 60 degrees. A change in the working position of the employee is required.



REBA - DATABASE
Export

Name of the worker	
Company	
Department	ÜRETİM
Function	F400
Description of the task	COMMISING

Neck:	0 to 20 degrees	Additional:	Neck is twisted or side bending
Trunk:	Straight	Additional:	No
Legs:	Support in one leg	Additional:	No
Load:	< 5 Kg	Additional:	No
Wrist:	More than 15 degrees up or down	Additional:	Wrist is bent from midline or twisted
Upper Arm:	More than 90 degrees	Additional:	No / Raised shoulder / No
Lower Arm:	0 to 60 degrees or more than 100 degrees	Coupling:	Fair
Activity 1:	One or more body parts are held for longer than 1 minute (static)		
Activity 2:	No		
Activity 3:	No		
Result:	7		10 of 10

Figure 3.19 Rotary and Current Transformer Section REBA score-2 (Personal archive, 2019)

Figure 3.19 illustrates that the assembly worker tilts his neck 20 degrees forward, use one leg, bends his upper arm more than 90 degrees and bends his lower arm more than 60 degrees. Then REBA score takes the value of 7, which means a change in the working position of the employee is required.

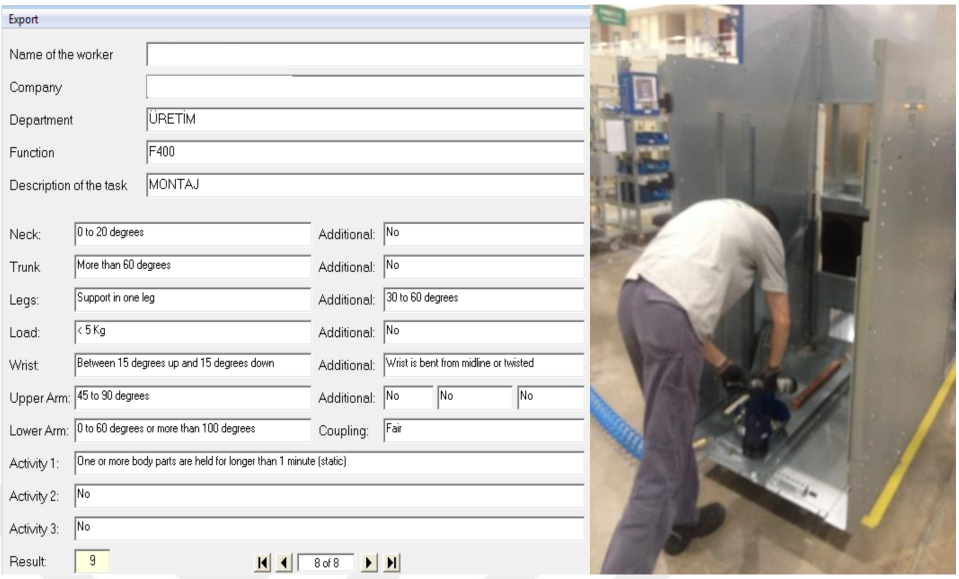


Figure 3.20 Rotary and Current Transformer Section REBA score-3 (Personal archive, 2019)

Figure 3.20 illustrates that the worker tilts his neck 20 degrees forward, tilts his body more than 60 degrees forward, use one leg to work, bends his upper arm more than 45 degrees, bends his lower arm more than 60 degrees. Consequently, REBA score takes the value of 9. It means that, there is an urgent need to change the working position of the employee.

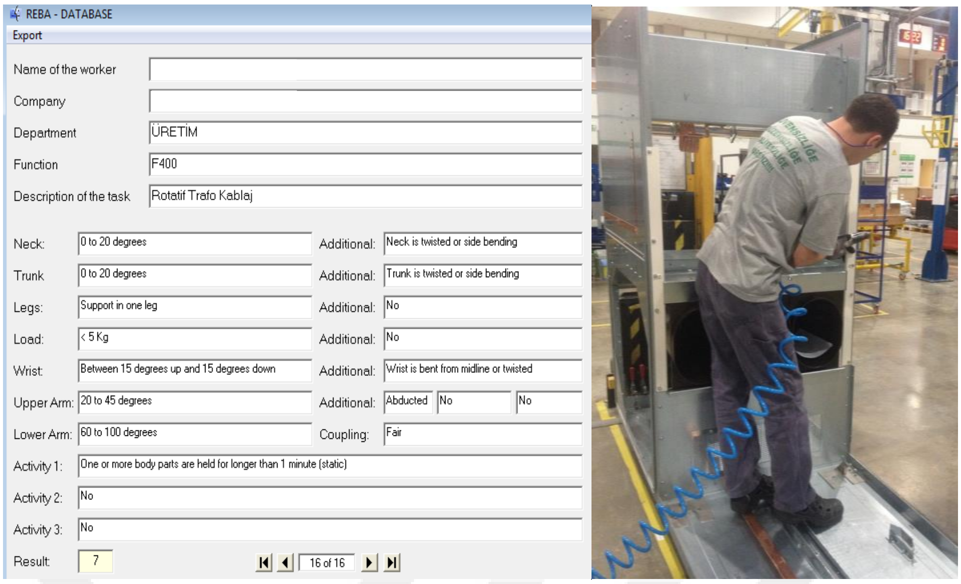


Figure 3.21 Rotary and Current Transformer Section REBA score-4 (Personal archive, 2019)

In Figure 3.21, the rotating transformer cabling worker in the production line bends his neck 20 degrees forward, his body 20 degrees forward, his upper arm 20 degrees, his lower arm more than 60 degrees and his wrists 15 degrees up and down, and loading it into one foot. Consequently, REBA score takes the value of 7. A change in the working posture of the employee is required.

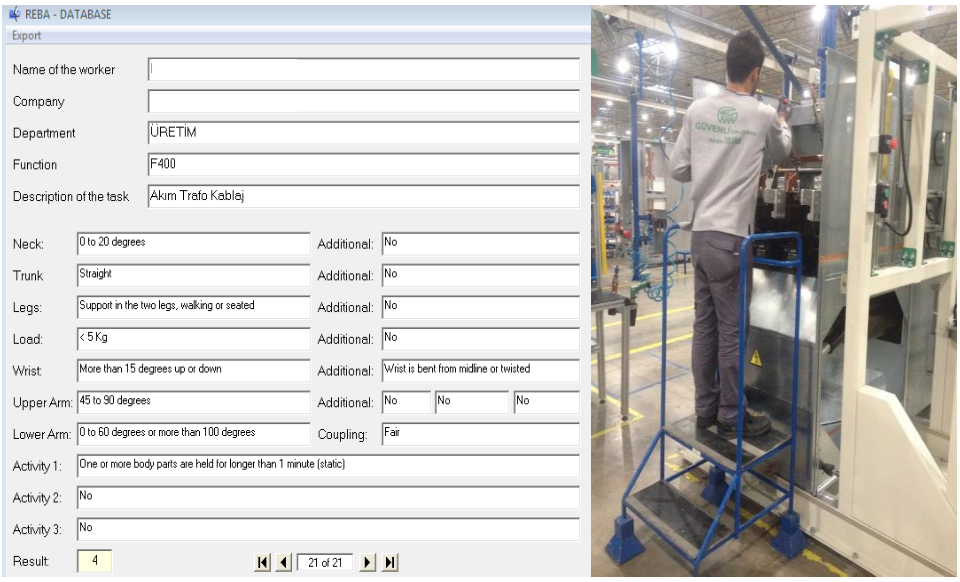


Figure 3.22 Rotary and Current Transformer Section REBA score-5 (Personal archive, 2019)

In Figure 3.22, the current transformer cabling worker tilts his front 20 degrees forward, bends his upper and lower arms more than 60 degrees and his wrists more than 15 degrees up and down. Then, REBA score takes the value of 4. This score can be reduced with a posture training given to the employee.

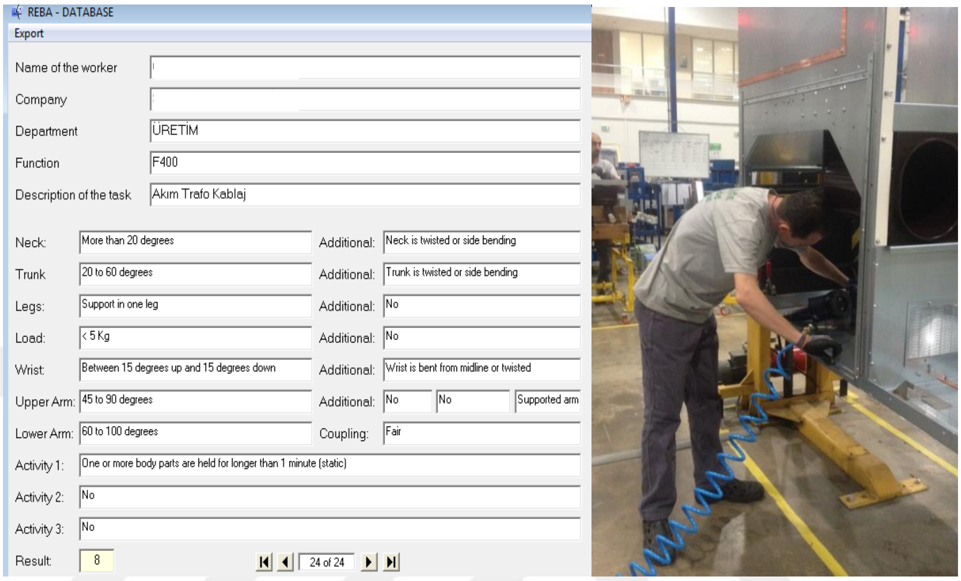


Figure 3.23 Rotary and Current Transformer Section REBA score-6 (Personal archive, 2019)

In, Figure 3.23 current transformer cabling worker tilts his neck more than 20 degrees forward, bends his body more than 20 degrees forward, his upper arm more than 60 degrees and his lower arm more than 45 degrees and his wrists more than 15 degrees up and down. In addition, he works on one leg. Consequently, REBA score takes the value of 8. There is an urgent need to change the working posture of the employee.

In the studies conducted in the Rotary and Current Transformer Section, 6 postures are analyzed. The age and disturbance distributions are reported in Table 3.9 and Figs. 3.24 and 3.25. As reported in Table 3.10, mean REBA score is 6.8, which means the postures have moderate risk. The results of the analysis expose that, the workers in Rotary and Current Transformer Section are mostly between the ages of 31-35 and 36-40. In addition, 25% of the disturbances are seen in the wrist, 25% in the waist, 25% in the forearm and 25% in the ankle. The REBA analysis reveals that work and workshop design is not suitable for the employees. inappropriate workbench design and wrong working posture cause disturbances. To overcome these disturbances, posture training should be given to the employees, work and workshop designs should be revised.

Table 3.9 Age and disturbance distribution of Rotary and Current Transformation Section

	Age	*Number*	*Disturbance*	*Number*
Rotary and Current Transformation	20-25	0	Ankle	1
	26-30	0	Knee	0
	31-35	2	Waist	1
	36-40	2	Back	0
	40+	1	Wrist	1
			Fore Arm	1
			Elbow	0
			Shoulder	0
			Neck	0

Table 3.10 REBA analysis results of Rotary and Current Transformation Section

Department	*Work*	*REBA Score*	*Risk Level*
Rotary and Current Transformer	Montage	6	Medium
	Montage	7	Medium
	Montage	9	High
	Rotary Transformer Wiring	7	Medium
	Current Transformer Wiring	4	Medium
	Current Transformer Wiring	8	High
Average REBA score		6.8	Medium

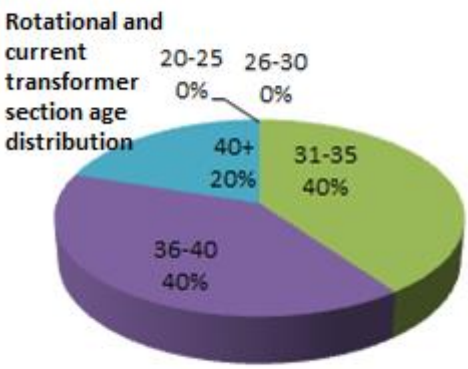


Figure 3.24 Age distribution in Rotary and Current Transformation Section

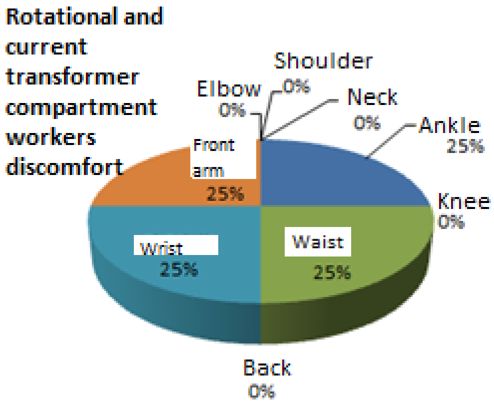


Figure 3.25 Distribution of disturbances in Rotary and Current Transformation Section

3.2.3 Door and Roof Assembly Section

In the Door and Roof Assembly Section, cable compartment base plate heating cell installation, LV cabinet hanging cabling, door installation, roof installation and right-left side sheet installation operations are performed. REBA analysis was made for 11 works in the Door and Roof Assembly Section.

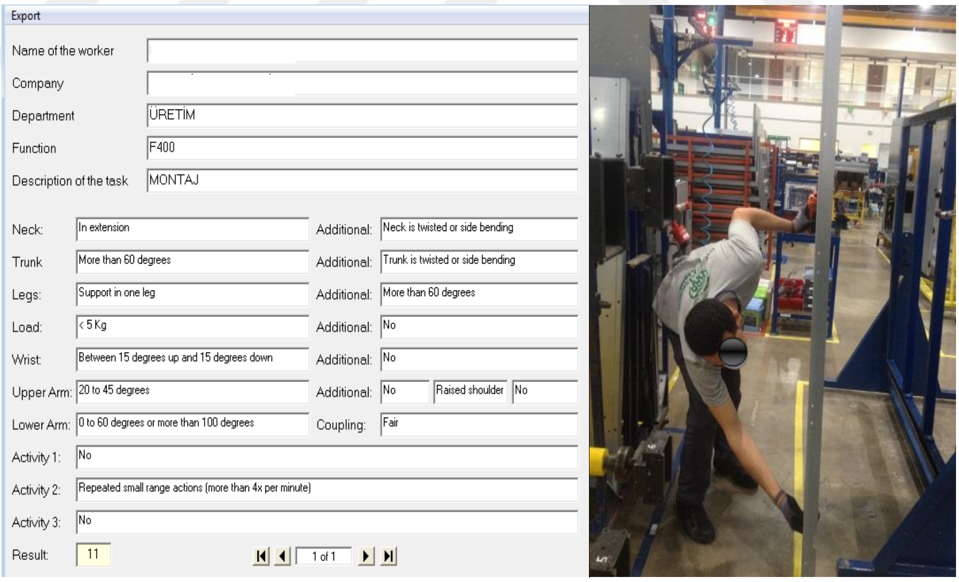


Figure 3.26 REBA score-1 in the Door and Roof Assembly Section (Personal archive, 2019)

In Figure 3.26, body of the worker bends over 60 degrees forward, the worker use his single leg, he bends his upper arm over 20 degrees and lower arm more than 60 degrees. Consequently, the REBA score takes the value of 11. Herein, an immediate change in the employee's work position is required.

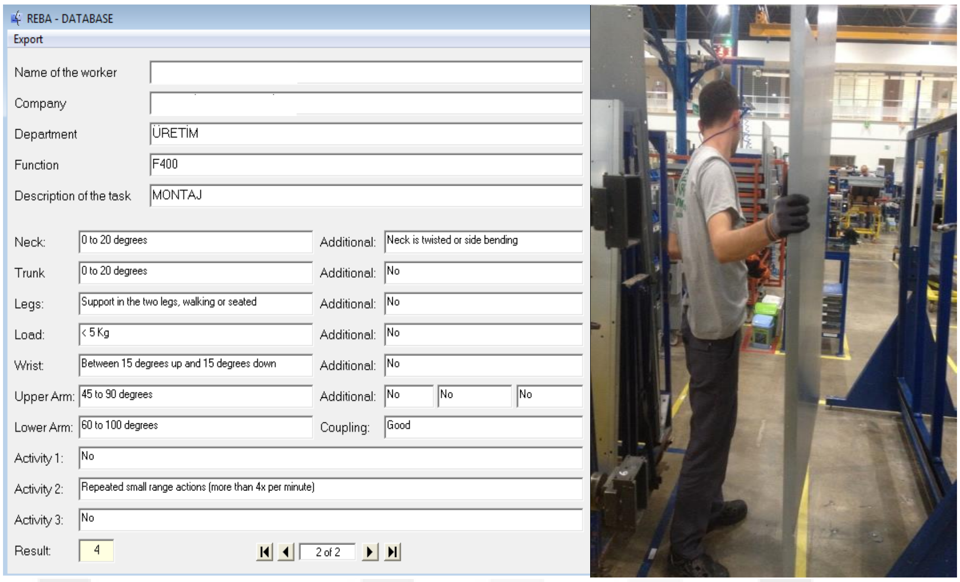


Figure 3.27 REBA score-2 in the Door and Roof Assembly Section (Personal archive, 2019)

In Figure 3.27, the REBA score is 4 as a result of the assembly in the production line. The worker bends his neck forward, his body 20 degrees forward, uses one leg, bends his upper arm more than 45 degrees and his lower arm more than 60 degrees. The work position of the employee should be changed.

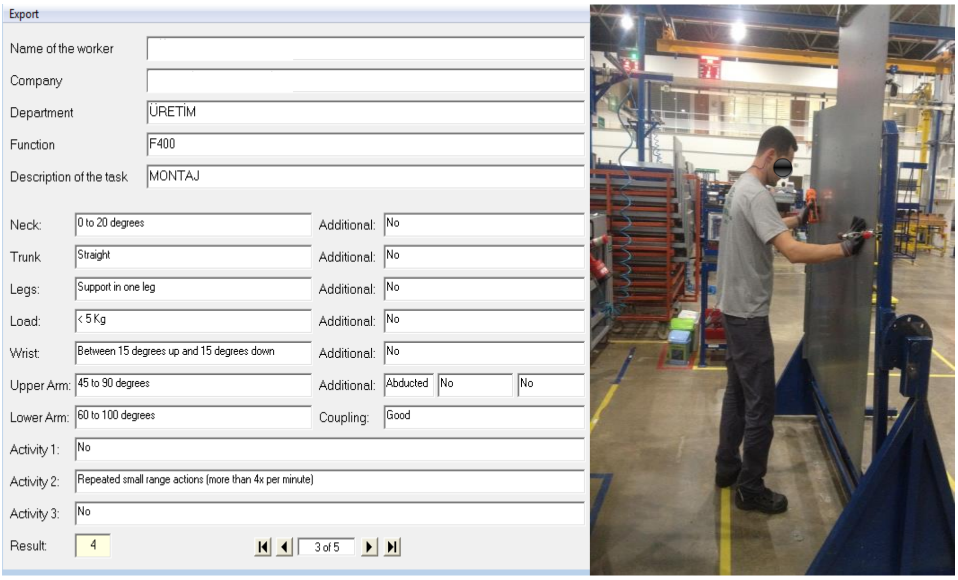
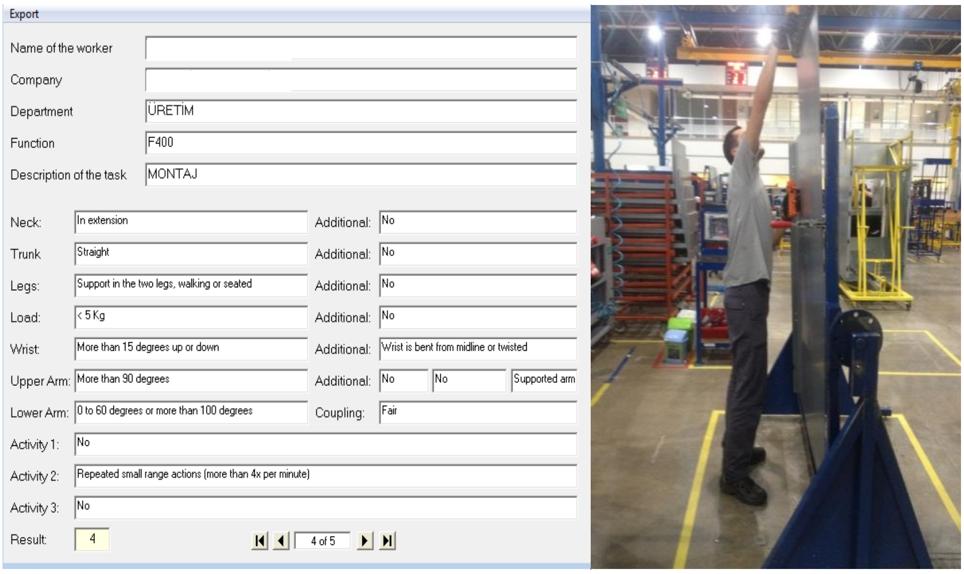


Figure 3.28 REBA score-3 in the Door and Roof Assembly Section (Personal archive, 2019)

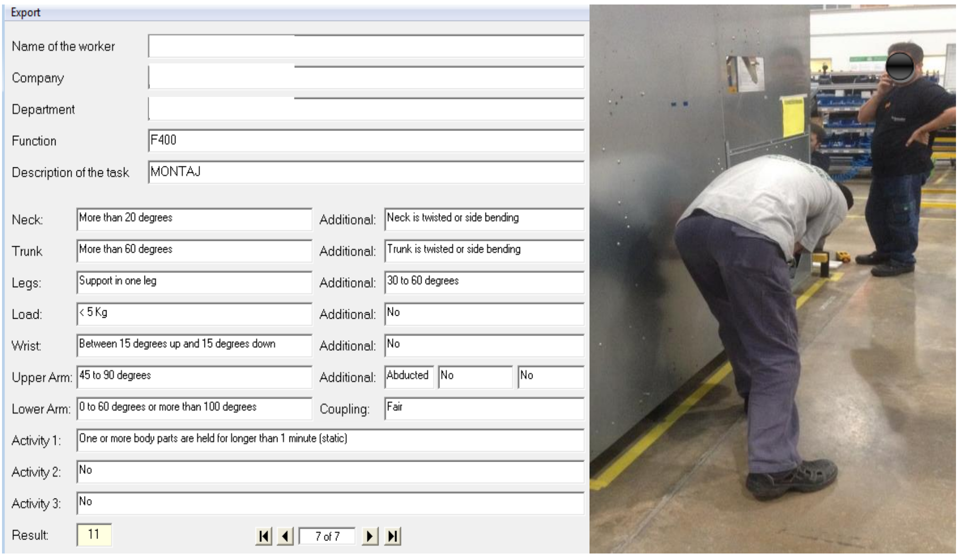
As illustrated in Figure 3.28, the REBA score is 4, which was obtained as a result of bending of the employee. The work position of the employee should be changed.


Export

Name of the worker			
Company			
Department	ÜRETİM		
Function	F400		
Description of the task	MONTAJ		
Neck:	In extension	Additional:	No
Trunk	Straight	Additional:	No
Legs:	Support in the two legs, walking or seated	Additional:	No
Load:	< 5 Kg	Additional:	No
Wrist:	More than 15 degrees up or down	Additional:	Wrist is bent from midline or twisted
Upper Arm:	More than 90 degrees	Additional:	No / No / Supported arm
Lower Arm:	0 to 60 degrees or more than 100 degrees	Coupling:	Fair
Activity 1:	No		
Activity 2:	Repeated small range actions (more than 4x per minute)		
Activity 3:	No		
Result:	4		4 of 5

Figure 3.29 REBA score-4 in the Door and Roof Assembly Section (Personal archive, 2019)

Figure 3.29 reports that the REBA score is 4 as a result of flexing back of the neck, bending the upper arm more than 90 degrees, bending the lower arm more than 100 degrees and bending the wrists more than 15 degrees. Herein, a step or platform design should be made to prevent the employee from reaching out. In addition, posture training should be given to the employee.


Export

Name of the worker			
Company			
Department			
Function	F400		
Description of the task	MONTAJ		
Neck:	More than 20 degrees	Additional:	Neck is twisted or side bending
Trunk	More than 60 degrees	Additional:	Trunk is twisted or side bending
Legs:	Support in one leg	Additional:	30 to 60 degrees
Load:	< 5 Kg	Additional:	No
Wrist:	Between 15 degrees up and 15 degrees down	Additional:	No
Upper Arm:	45 to 90 degrees	Additional:	Abducted / No / No
Lower Arm:	0 to 60 degrees or more than 100 degrees	Coupling:	Fair
Activity 1:	One or more body parts are held for longer than 1 minute (static)		
Activity 2:	No		
Activity 3:	No		
Result:	11		7 of 7

Figure 3.30 REBA score-5 in the Door and Roof Assembly Section (Personal archive, 2019)

In Figure 3.30, the REBA score is 11 as a result of bending the neck more than 20 degrees forward, bending the body more than 60 degrees forward, using one leg, bending the upper arm more than 45 degrees and bending the lower arm more than 60 degrees. Therefore, an immediate change in the employee's work position is required.

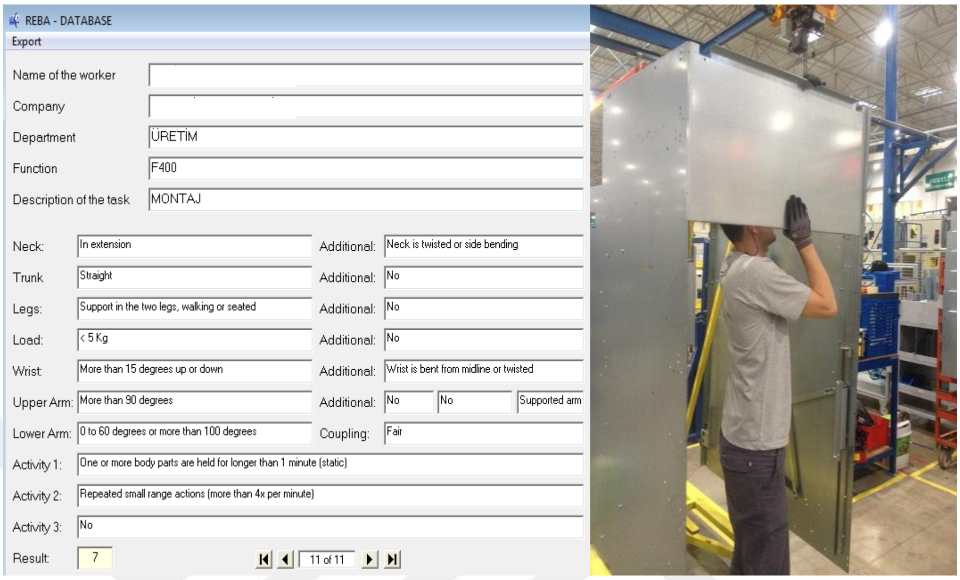


Figure 3.31 REBA score-6 in the Door and Roof Assembly Section (Personal archive, 2019)

In Figure 3.31, the REBA score of 7 is obtained as a result of bending the lower arm as much as 90 degrees. The employee's work position needs to be changed.

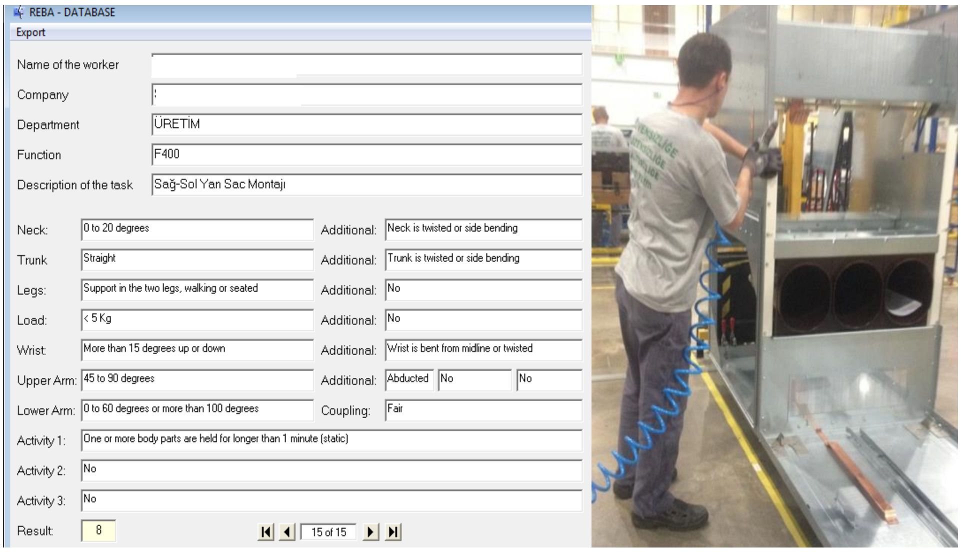


Figure 3.32 REBA score-7 in the Door and Roof Assembly Section (Personal archive, 2019)

As illustrated in Figure 3.32, right-left side sheet assembly worker bends his neck 20 degrees forward and bends his upper arm. Herein, the REBA score is 8. An immediate change in the employee's work position is required.

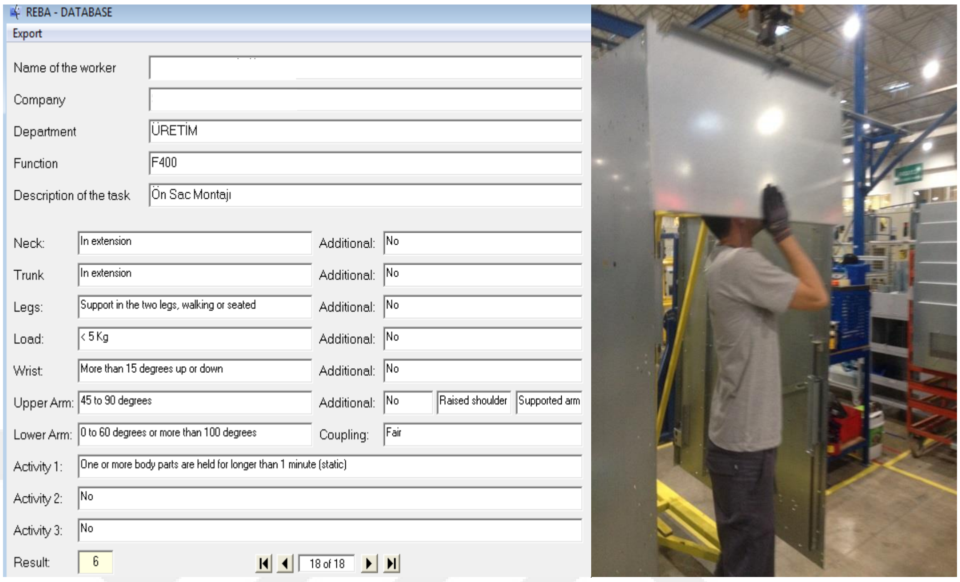


Figure 3.33 REBA score-8 in the Door and Roof Assembly Section (Personal archive, 2019)

Figure 3.33 illustrates that the REBA score is 6 as a result of backward flexing of the body, bending upper arm 45 degrees and lower arm more than 60 degrees and bending the wrists. The employee's work position needs to be changed.

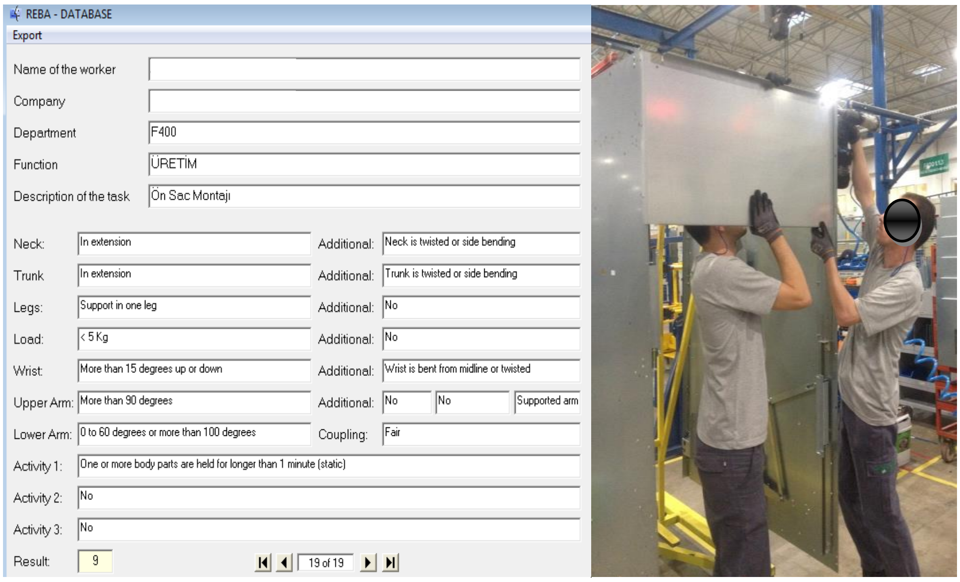
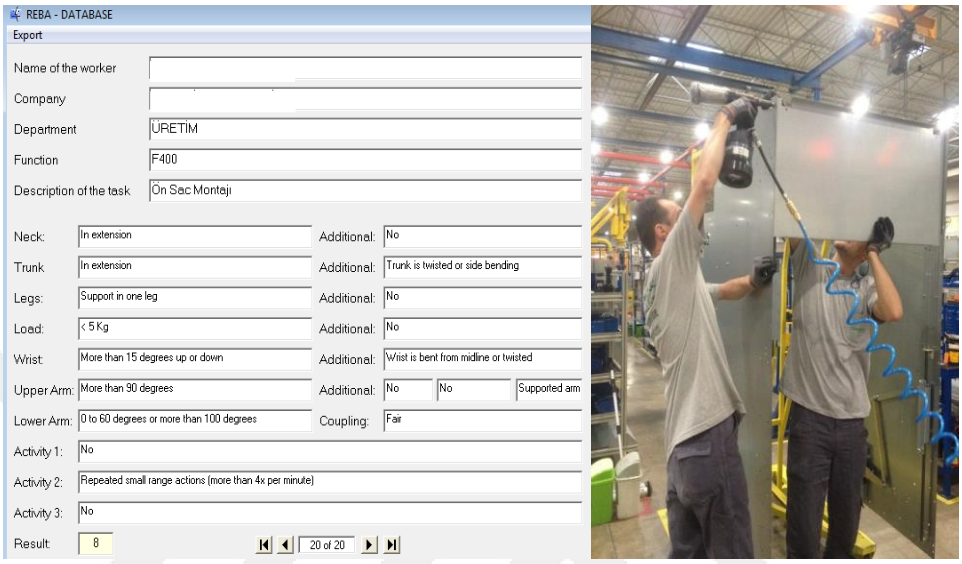


Figure 3.34 REBA score-9 in the Door and Roof Assembly Section (Personal archive, 2019)

Figure 3.34 reports that the REBA score is 9 due to the backward flexing of the body, bending upper arm 90 degrees and lower arm more than 60 degrees and wrists more than 15 degrees. An immediate change in the employee's work position is required.



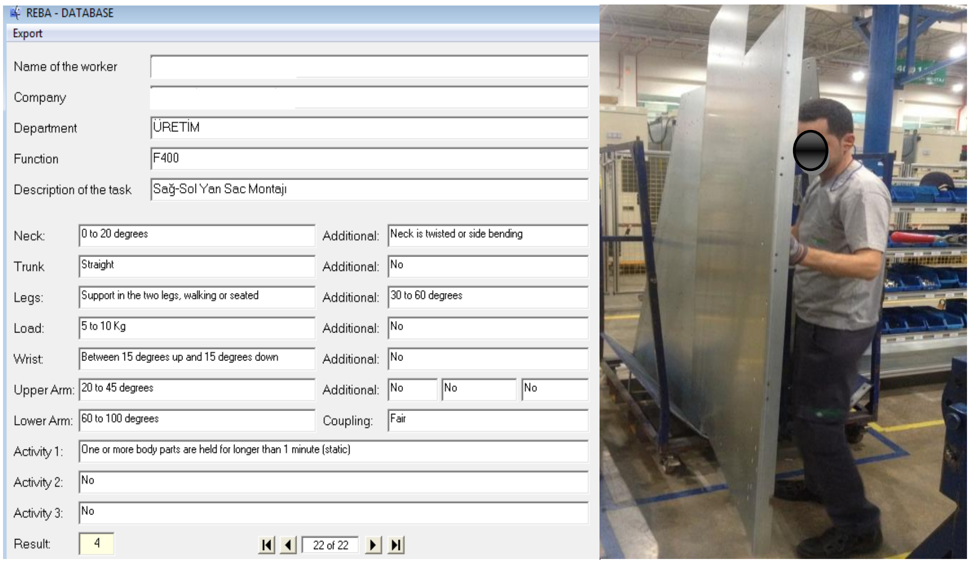
REBA - DATABASE
Export

Name of the worker	
Company	
Department	ÜRETİM
Function	F400
Description of the task	Ön Sac Montajı

Neck:	In extension	Additional:	No
Trunk	In extension	Additional:	Trunk is twisted or side bending
Legs:	Support in one leg	Additional:	No
Load:	< 5 Kg	Additional:	No
Wrist:	More than 15 degrees up or down	Additional:	Wrist is bent from midline or twisted
Upper Arm:	More than 90 degrees	Additional:	No / No / Supported arm
Lower Arm:	0 to 60 degrees or more than 100 degrees	Coupling:	Fair
Activity 1:	No		
Activity 2:	Repeated small range actions (more than 4x per minute)		
Activity 3:	No		
Result:	8		20 of 20

Figure 3.35 REBA score-10 in the Door and Roof Assembly Section (Personal archive, 2019)

Figure 3.35 illustrates the front sheet assembly. The REBA score is 8 due to flexing the body back, and bending upper arm and wrists. An immediate change in the employee's work position is required.



REBA - DATABASE
Export

Name of the worker	
Company	
Department	ÜRETİM
Function	F400
Description of the task	Sağ-Sol Yan Sac Montajı

Neck:	0 to 20 degrees	Additional:	Neck is twisted or side bending
Trunk	Straight	Additional:	No
Legs:	Support in the two legs, walking or seated	Additional:	30 to 60 degrees
Load:	5 to 10 Kg	Additional:	No
Wrist:	Between 15 degrees up and 15 degrees down	Additional:	No
Upper Arm:	20 to 45 degrees	Additional:	No / No / No
Lower Arm:	60 to 100 degrees	Coupling:	Fair
Activity 1:	One or more body parts are held for longer than 1 minute (static)		
Activity 2:	No		
Activity 3:	No		
Result:	4		22 of 22

Figure 3. 36 REBA score-11 in the Door and Roof Assembly Section (Personal archive, 2019)

Figure 3.36 illustrates the right and left sides plate assembly work. The REBA score takes the value of 4 due bending to the front 20 degrees, and bending the upper arm 20 to 45 degrees. This score can be reduced by training the employee.

Table 3.11 REBA analysis result for the Door and Roof Assembly

	Work	*REBA Score*	*Risk Level*
Door and Roof Assembly	Side sheet installation	11	Very High
	Installation	4	Middle
	Installation	4	Middle
	Installation	4	Middle
	Installation	11	Very High
	Installation	7	Middle
	Right and left side Installation	8	High
	Front sheet Installation	6	Middle
	Front sheet Installation	9	High
	Front sheet Installation	8	High
	Right-left side sheet Installation	4	Middle
Average REBA Score		*6.9*	*Middle*

Table 3.12 Age and disturbance distribution of Door and Roof Assembly employees

	Age	*Number*	*Disturbance*	*Number*
Door and Roof Assembly	20-25	0	Ankle	0
	26-301		Knee	1
	31-352		Waist	3
	36-402		Back	2
	40+	3	Wrist	0
			Front Arm	0
			Elbow	1
			Shoulder	1
			Neck	3

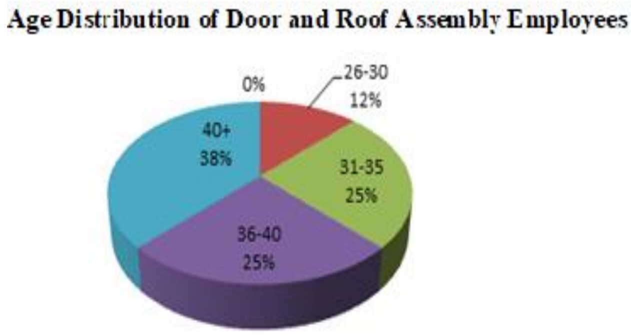


Figure 3.37 Age distribution of Door and Roof Assembly employees

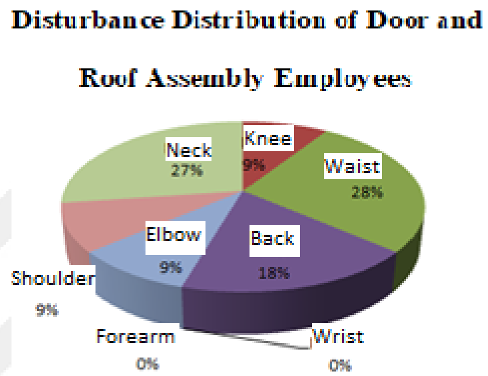


Figure 3.38 Disturbance distribution of Door and Roof Assembly Employees

In the Door and Roof Assembly Section, 11 works were analyzed as reported in Table 3.11. The age and disturbance distribution of the employees are presented in Table 3.12. The average REBA score is 6.9, indicating a moderate risk of posture. The analysis points out that, 38% of the employees in the Door and Roof Assembly Section are 40 years and over age, 25% are 31-35 years of age, 25% are 36-40 years of age and 12% are 26-30 years of age. 28% of the disorders are the waist disturbances, 27% of them are neck disturbances and 18% of them are back disturbances. The results of the survey and the REBA analysis support each other. The results coincide with the complaints in the survey. The design of the work shop is not suitable for the workers, and wrong working postures exists. The proposed improvements should be applied to prevent these disorders.

The average REBA score for the three Section, Topay Assembly, Rotary and Current Transformation and Door and Roof Assembly, is calculated as 6.43.

CHAPTER FOUR
CONCLUSIONS

One of the biggest risks in today's societies are injuries, disability, labor losses and chronic complaints. In addition, continuity of production activities and production efficiency is the most important concern for companies. Today, work-related MSDs are important health problems and represent the majority of occupational pathologies. MSDs result in work restrictions, decrease in quantity and quality of work, productivity, quality of life, and increase in loss of working time, wage compensations and medical expenses. Uncomfortable working postures cause MSDs by increasing biomechanical overload in the different body regions, and consequently increase work accidents. Therefore, analysis of the postural attitudes of the employees during the interaction with working environment is crucial in prevention of ergonomic risks caused by biomechanical overload.

This study aims to examine the risk factors of MSDs associated with different work postures of the employees in an international manufacturing firm by using ergonomic evaluation criteria. To this aim, the risky production divisions of the firm are determined by a survey firstly. Then, risk levels of the tasks for the selected production divisions are measured by using REBA method, which is a common ergonomic tool used to facilitate the measurement and evaluation of whole-body postural risks associated with job tasks.

The average REBA score for the 25 works in the predetermined sections of the firm, Topay Assembly, Rotary and Current Transformation and Door and Roof Assembly, is calculated as 6.43. The REBA analysis reveal that some employees adopted unfavorable working postures making them susceptible to moderate to high risk of future musculoskeletal disorders. The measures to be taken towards proper working are suggested to the management of the firm.

It is observed in this study that employees often work in faulty postures, and posture training is not sufficient. Workers in continuous standing position are often exposed to bending and reaching out. This would cause occupational musculoskeletal disorders in the long term. In order to prevent disturbances, posture training should be provided to the employees. Another measure is to redesign the works and workshop in a way that eliminates reaching and bending movements as much as possible.

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APPENDICES

Table A.1 The Survey Form

1	**PERSONAL INFORMATION**								
2	SEX	FEMALE	MALE						
3	AGE	20-25	25-30	30-35	40+				
4	TITLE								
5	DEPARTMENT								
6	HOW LONG HAVE YOU BEEN WORKING?								
7	HOW LONG HAVE YOU BEEN WORKING IN THIS BUSINESS?								
8	**QUESTIONS ABOUT BUSINESS AND WORKPLACE**								
9	IF YOU SITTING AT WORK, IS YOUR SEAT COMFORTABLE?	YES	NO						
10	ARE YOU ABLE TO MOVE FREELY IN THE WORK AREA?	YES	NO						
11	DOES THE EQUIPMENTS' SETTLEMENT FIT INTO YOUR WORK?	YES	NO						
12	IS THE HEIGHT OF THE BENCH APPROPRIATE?	YES	NO						
13	IS THE BREAK TIMES LONG ENOUGH?	YES	NO						
14	IS YOUR WORK ENVIRONMENT IS RISKY?	YES	NO						
15	DO YOU FEEL SAFE AT WORK?	YES	NO						
16	**QUESTIONS ABOUT THE EQUIPMENTS**								
17	DO YOUR WORK EQUIPMENTS FIT IN YOUR HAND?	YES	NO						
18	ARE YOU CARRYING A HEAVY LOAD?	YES	NO						
19	**OCCUPATIONAL DISORDERS**								
20	DO YOU HAVE ANY DISORDER?	FOOT	KNEE	WAIST	WRIST	FRONT ARM	ELBOW	SHOULDER	NECK
21	IF ANY, WHAT IS THE SEVERITY OF YOUR DISORDER?	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
22		MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM
23		HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
24	HOW LONG HAS IT BEEN HURTING?								
25	HOW OFTEN DID YOU APPLY TO THE DOCTOR FOR YOUR DISORDERS IN THE LAST 1 YEAR?	NEVER	1	2-9	10+				
26	DO YOU THINK THAT YOUR DISORDERS ARE CAUSED FROM THE WORK ENVIRONMENT?	YES	NO						