DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

ASSESSMENT AND MANAGEMENT OF ERGONOMIC RISKS IN A MANUFACTURING FIRM

by
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İZMİR

ASSESSMENT AND MANAGEMENT OF ERGONOMIC RISKS IN A MANUFACTURING FIRM

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Zehra Nur ATALAY

ASSESSMENT AND MANAGEMENT OF ERGONOMIC RISKS IN A MANUFACTURING FIRM

ABSTRACT

Ergonomics is a multidisciplinary science that aims to create harmony between the employees and their work, with the goal of preventing accidents and injuries, reducing time losses and costs, and increasing safety, efficiency, and comfort through the application of many sciences (anatomy, anthropometry, physiology, psychology, and so on), while taking into account the physical, biological, and psychological characteristics of the employees. To put it another way, it ensures that the job is suited to the employees, not the other way around. One of the issues that ergonomics focuses on is working positions in labor-intensive industrial processes. Work-related musculoskeletal disorders (MSDs) are a prevalent health concern that emerges as a result of exposure to certain dangers during unsuitable working positions and work-related activities. They constitute the vast majority of occupational diseases. Work-related MSDs lead to an increase in workplace accidents, a deterioration in quality of life and productivity, and an increase in health expenditures and costs. Thus, a thorough examination of ergonomic risks associated with working situations has a critical important.

The aim of this study is to assess employees' risks of work-related MSDs in a manufacturing company. The Rapid Entire Body Assessment (REBA) approach, which is extensively employed in the ergonomic evaluation of the risks of positions that deal with the entire body, is used to evaluate the risk levels of the employees' working positions in various departments and stations. This method, which is based on observation and allows for the analysis of both dynamic and fixed postures, enables the assessment of work-related musculoskeletal system risk levels and the implementation of appropriate safeguards. As a result of the analyzes carried out with the REBA method, it has been determined that some employees have working positions at medium and high risk levels. The actions and the measures to be taken to reduce the risk levels were shared with the company managers.

Keywords: Ergonomics, ergonomic risk assessment, working position, work-related musculoskeletal disorders, REBA

BİR İMALAT FİRMASINDA ERGONOMİK RİSKLERİN DEĞERLENDİRİLMESİ VE YÖNETİMİ

ÖZ

Ergonomi; çalışanların fiziksel, biyolojik ve psikolojik özelliklerini dikkate alan, anatomi, antropometri, fizyoloji, psikoloji gibi birçok bilim alanından faydalanarak kazaları ve yaralanmaları önlemeyi, zaman kayıplarını ve maliyeti azaltmayı, güvenliği, verimliliği ve konforu artırmayı amaçlayan, çalışanlar ile yaptığı işler arasındaki uyumu sağlamaya çalışan çok disiplinli bilim dalıdır. Başka bir ifadeyle, çalışanların işe değil işin çalışanlara uyumlandırılmasının sağlanmasıdır. Emek yoğun üretim sistemlerindeki çalışma pozisyonları ergonominin odaklandığı konulardan biridir. Uygun olmayan çalışma pozisyonları ve işler sırasında bazı risklere maruz kalınması sonucunda oluşan Mesleki Kas İskelet Sistemi Rahatsızlıkları (MKİSR) sıklıkla görülen bir sağlık sorunudur ve mesleki rahatsızlıkların büyük çoğunluğunu temsil etmektedir. MKİSR, iş kazalarında artışa neden olmakta, yaşam kalitesi ve üretkenliği düşürmekte, sağlık harcamaları ve maliyetleri artırmaktadır. Tüm bu nedenler dikkate alındığında, çalışma pozisyonlarına ilişkin ergonomik risklerin analizi oldukça önemlidir.

Bu çalışmanın amacı, bir imalat firmasındaki çalışanların mesleki kas iskelet sistemi rahatsızlıklarına ilişkin riskleri analiz etmektir. Farklı bölüm ve istasyonlarda bulunan çalışanların çalışma pozisyonlarının risk seviyeleri, tüm vücudu ele alan pozisyonların risklerinin ergonomik açıdan değerlendirilmesinde yaygın olarak kullanılan Hızlı Tüm Vücut Değerlendirme (REBA) yöntemi ile hesaplanmıştır. Gözleme dayalı ve hem dinamik hareketlerin hem de sabit duruşların incelenmesine imkan veren bu yöntem, mesleki kas iskelet sistemi risk seviyelerinin tespit edilmesini ve gerekli önlemlerin alınmasını sağlar. REBA yöntemi ile gerçekleştirilen analizler sonucunda, bazı çalışanların orta ve yüksek risk seviyelerinde çalışma pozisyonlarına sahip oldukları belirlenmiştir. Risk seviyelerini

azaltmaya yönelik yapılması gerekenler ve alınması gereken önlemler firma yöneticileri ile paylaşılmıştır.

Anahtar kelimeler: Ergonomi, ergonomik risk değerlendirme, çalışma pozisyonu, mesleki kas iskelet sistemi rahatsızlıkları, REBA

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CHAPTER ONE
INTRODUCTION

1.1 Introduction

The rapid development of technology in the globalizing world and the beginning of the information age have not only made things easier in many areas of life, but also changed the understanding of manufacturing. The place of machines and automation in production is increasing day by day. This increase speeds up and makes things easier. Despite this, there is still labor-based production in many enterprises and workers are exposed to intense physical loads. Work-related musculoskeletal disorders, which include back, neck, wrist, arm, and leg pains, are prevalent among employees.

The goal of ergonomics, which is a science that aims to provide human-machine-environment harmony in the face of all physiological and psychological stresses, is primarily to prevent diseases and injuries by improving the working conditions of employees, to increase earnings by raising productivity and to accelerate the return on investment. One of the issues that ergonomics emphasizes in labor-intensive production systems is working postures. In this study, the REBA method, which is one of the ergonomic risk assessment methodologies, was used to examine working postures in a manufacturing company, and employees with medium and high risk levels were ascertained.

1.2 Aim of The Thesis

The aim of this study is to conduct ergonomic analyses of employees' working positions in production stations of a manufacturing company, as well as to assess the risks of work-related MSDs. In the examination, the REBA method, which is a widespread ergonomic risk assessment method was employed. The actions and the measures to be taken to reduce the risk levels were shared with the company managers.

The remaining sections of the thesis are constituted as in the following. The second section gives general information on ergonomics and work-related musculoskeletal disorders. Chapter 3 includes the literature review on the related body of knowledge. The REBA method, the ergonomic risk assessment method utilized in this thesis, is explained in the fourth chapter. In Chapter 5, the application carried out in a manufacturing company is presented. Finally, in Chapter 6, the results and concluding remarks are presented.

CHAPTER TWO
ERGONOMICS AND MUSCULOSKELETAL DISORDERS

2.1 Definition of Ergonomics

The term "ergonomics" is derived from the Greek terms "ergon" (labor) and "nomos" (law). It has been defined in a variety of ways throughout history. The application of scientific information about humans to the design of items, systems, and environments for human use is known as ergonomics. Ergonomics is the science of matching the work with the employee and the product with the user, based on work productivity, health, safety, comfort, and simplicity of use (Pheasant, 1991).

Bridger (2003) defines ergonomics as a discipline that studies the human-machine interface and the factors that influence that connection. Ergonomics, according to Colovic (2014), is an interdisciplinary science that deals with the human-machine system and how to adapt the machine to human biopsychosocial limits and demands. Wilson (2000) defines ergonomics as the basic understanding of human behavior and performance in sociotechnical systems, as well as its application to the design of their interactions in real-world settings.

According to Zunjic (2017), the definition of ergonomics is expressed as follows.

Ergonomics is a multidisciplinary science whose goal is to examine the impact of means of work, conditions of work, processes of work, and products as results of work on humans from the psychological, physiological, anatomical, biomechanical, sociological, organizational and physics aspect by applying the quantitative and qualitative research methods, as well as to adapt the design of the aforementioned elements to humans, with the aim of improving comfort, safety, efficiency and satisfaction, which are considered during their interaction with humans.

Human engineering, human factors engineering, engineering psychology, man-machine systems, and human-machine interface design are all terms used to describe the discipline of ergonomics (Bhise, 2012). While the phrase "human factors" is frequently used instead of "ergonomics," the term "ergonomics" has its origins in Europe (Zunjic, 2017).

2.2 Aims of Ergonomics

The aim is to improve the human-machine interaction in question in order to boost system performance. As a result, work environments, tasks, and elements in job structure that reduce human-machine performance can be studied and modified. Ergonomics is concerned with creating a better "working system", not with improving "people management." It should provide the system better by attempting to reduce the system's omitted, uncontrolled, and undesired elements (Bridger, 2003).

Ergonomics is concerned with people and their job, and it investigates human physical and psychological abilities and limitations, emphasizing that they should not be exceeded. As a result, the aim of ergonomics is to provide an environment that is both comfortable and reliable for employees while also meeting the organization's goals and objectives (Jaffar, Abdul-Tharim, Mohd-Kamar, & Lop, 2011).

Colovic (2014) mentioned that the aim of ergonomics is to be adapted to working condition, working style, working process, and the product and is to be studied as a result of human work from the psychological, physiological and anatomical aspects, instead of adjusting human to the needs of a job.

Three aspects of the adaptation to people of the work are mentioned.

-Adjusting the machines and tools that need to be designed, built and shaped considering the anatomical and physiological characteristics, abilities and limitations of human beings,

-Adjusting working methods according to body positions and movements (Thus, it should be ensured that the maximum effect is given in the working method by reducing stress and fatigue),

- Adjusting the working environment according to the objective physical conditions to create a comfortable area.

The goals of ergonomics, according to Yamankaradeniz, Kılık, and Akalp (2020), are to provide the best performance with the least amount of manpower (stress, strain, fatigue, accidents), improve working postures, establish a balance between employee abilities and work, ensure worker health and safety, and increase productivity.

Among the goals of ergonomics are to design work in accordance with human anthropometric measurements, to create a safe and suitable environment for health conditions and to ensure worker health and safety, to reduce work accidents, fatigue, and stress, to make all tools, machinery and equipment suitable for human beings, and to create a positive psychosocial environment (Köksüz, 2019).

2.3 Components of Ergonomics

Ergonomics comprises three components, according to the International Ergonomics Association (IEA). Physical ergonomics is the first, and it is concerned with physical activity. It has to do with human anatomical, anthropometric, physiological, and biomechanical characteristics. It covers musculoskeletal diseases in the workplace, working postures, repetitive movements, workplace layout, safety, health, and material use. The second component, cognitive ergonomics, studies the interactions between humans and other system parts, including mental processes. It includes problems such as job stress connected to human-machine interaction, performance, decision making, mental strain, human-system design, and training. Organizational ergonomics, which is the third component, contains organizational structures, policies and processes. Communication, teamwork, community ergonomics, job design, time design, collaborative work, new working paradigms, teleworking and quality management are covered within organizational ergonomics (Akpınar, Çakmakkaya, &Batur, 2018; McCauley Bush, 2011).

2.4 Historical Development of Ergonomics

With circumstances such as wars, natural disasters, and prominent people, changes in ergonomics have continued throughout human history. Because of the accumulation of life, accommodation, sheltering types, utilized items, living environment, and many other elements, ergonomics has emerged in Egyptian, Chinese, Arab, Indian, and Asian-Turkish civilizations. While anthropometric measurements were taken into account in the clothing and furniture used in Egyptian kingdoms, buildings in Asia and Anatolia were built to be warm in the winter and cool in the summer, and window types extending from the outside to the inside were used to provide illumination and spread the light uniformly. Ergonomics has benefited from advancements in occupational health and safety. Hippocrates (460-370 B.C.) talked about lead poisoning, Plato (428-348 B.C.) problems with craftsmen's working conditions, and Aristotle (384-322 B.C.) health issues with runners. Dr. Galen, on the other hand, concentrated in the second century on the role of the environment in diseases. Agricola (1494-1555) proposed preventive measures, but Juvenal highlighted varicosis in laborers and eye diseases among blacksmiths (Akpınar, Çakmakkaya, &Batur, 2018).

The scientific investigations of the Italian Bernardino Ramazzini (1633-1714) on work and sickness in the 17th century were generally acknowledged. Ramazzini, known as the "father of occupational health", wrote a book in 1713 titled "Worker Diseases" that detailed occupational diseases. Ramazzini has consistently emphasized the relevance of the link between work and sickness in medicine, claiming that reducing improper work settings will boost productivity. Furthermore, for the first time, the idea that ergonomics, defined as the adaptation of the task to the individual, has an impact on employee health and productivity was emphasized. In a paper published in 1857 by Polish Professor Wojciech Jastrezebowski, the concept of ergonomics was first mentioned. Jastrezebowski argued in the paper that the issues caused by work for employees should be studied scientifically, and that a separate field should be founded for these research. Jastrezebowski coined the term "ergonomics" to describe this branch of research, but it has since been forgotten (Akpınar, Çakmakkaya, &Batur, 2018).

Industrial production was still reliant on manpower at the turn of the 1900s, but with the development of ergonomic concepts, scientific management approaches, and business processes, productivity rose and created popularity. The practice-based history of ergonomics is made up of studies for economic goals. Humans were viewed as "machines" during a period when the goal of increasing production, profit, and productivity was prevalent. Later, it was realized that this impression was incorrect, and it was recognized that using both physical and mental strengths till the last could bring health problems.

Mechanical engineer F.W. Taylor is credited for developing the concept of "work array" and proposing and testing numerous hypotheses for workers to operate more effectively in the history of ergonomics. Taylor has also been criticized for his "selection of workers and raising wages" techniques to increasing worker motivation and productivity. Despite being paid more, the workers were dissatisfied with the hand tools and fast pace of work devised by Taylor. In addition to all of this, Taylor is credited with being the first researcher to suggest a "wage approach to job enthusiasm" in both ergonomics and social psychology. In the 1910s, two innovative projects that pioneered ergonomic techniques attracted notice. The first is the work and time study established by engineer Gilbreth and his psychologist wife, and the second is the work of Douglas, who invented the oxygen consumption formula to calculate energy expenditure while working and is famed for his gas-tight sampling bags. These two methodologies are still in use today, with improved methods (Köksüz, 2019).

Experts in applied psychology pioneered the field of ergonomics. Munsterberg's paper in 1913, "Psychology in Industrial Activities," is a ground-breaking work on the subject. Cambridge University developed the first Experimental Psychology

Laboratory in 1921. The Fatigue Research Board was founded in England after World War I, and it promoted experimental studies and applied research until the National Institute of Industrial Psychology was established. Many people died as a result of human or machine faults during the Second World War because the concept of human-machine systems was overlooked. The importance of the human component in the design of all types of instruments and equipment to be developed has been realized as a consequence of the investigation of the subject. In England, the Oxford Medical Research Unit and the Cambridge Applied Psychology Unit were founded after World War II (Köksüz, 2019).

The Dayton Aeromedical Laboratory Psychology Branch was established in the United States to do research. Problems between humans and machines were considered in these companies rather than human and work psychology. The British Land Forces are likewise formed to provide their specific requirements. In the United States, ergonomic studies are referred to "Human Engineering", "Human Factor Engineering", and "Human Factor". In the same period, the British Armed Forces focused on equipment design and established a research group. Working with the Navy's Applied Research Unit, an Operations Activities Committee has been formed. At the same time, the Land Forces Command established Army Operation Research Group, and the Farbourg Air Force Institute of Aviation Medicine conducted these investigations in the Air Force. The Knobs and Dials Ergonomics Era refers to these phases in ergonomics history (Köksüz, 2019).

Because the work done until the 1940s was dispersed, a meeting was conducted in 1949 at Oxford University under the presidency of Murrell. The word "ergonomics" was proposed at a meeting with academics from many disciplines of competence (anatomy, anthropology, physiology, psychology, engineering sciences, etc.) and all studies were grouped under one title. A scientific approach has emerged, which includes approaches like Human Factors Engineering in the United States, Biotechnology in Sweden, Applied Psychology in the United Kingdom, and Arbeit Physiology in Germany, and also involves fields of interest like Industrial Psychology, Work Study, and Human Biodynamics. From 1949 until the present, the study of ergonomics has progressed in various directions. Control mechanisms, indications, machine size, and panels were initially considered, but following the Oxford meeting, it began to be discussed more broadly. The formation of the "Ergonomics Research Council" was the first move in this direction. Despite the fact that this organization aimed for international cooperation, it was merged at an international convention in Stockholm in 1961, and the “International Ergonomics Society” was founded as a result of this meeting (Köksüz, 2019; Akpınar, Çakmakkaya, &Batur, 2018).

In general, if we want to look at the development of the concept of ergonomics in the world chronologically; the emergence of ergonomics in the 1950s took place in the military field and military ergonomics was dominant in those years, industrial ergonomics was studied in the 1960s, ergonomics aimed at designing according to consumer priorities in the 1970s was at the forefront, human and computer interaction and software ergonomics in the 1980s and cognitive and organizational ergonomics in the 1990s, and global communication and eco-ergonomics (ecological and economic ergonomics) in the 2000s (Akpınar, Çakmakkaya, &Batur, 2018).

In Turkey, since the 1960s, there has been an interest in issues related to ergonomics. "Live Force Resources in Agriculture" chair was established at Ankara University Faculty of Agriculture (Akpınar, Çakmakkaya, &Batur, 2018). Ergonomics was started to be taught in the "Business Science" course at İstanbul Technical University in 1969, and there was a tendency towards anthropometric research in the industry in practice. In 1968, the Ministry of Labor and the World Labor Organization started to work to establish a modern Occupational Health and Safety Center. The ergonomics unit with modern devices was established here in 1972. Ergonomics was included in the training program under the name of Human Factors Engineering in the Department of Industrial Engineering at Middle East Technical University in 1971, and a laboratory was constituted in 1975 with devices brought from abroad. In the 1980s, Dokuz Eylül University Industrial Engineering Department included the "Ergonomics" courses in its education program and organized the Turkish-German Ergonomics Symposiums in 1984 and 1986. These symposiums have been an important resource. The National Productivity Center has a very important place in introducing ergonomics to the business world in our country. Seminars such as "Ergonomics", "Improving the Physical Environment at Workplaces", "Contribution of Industrial Engineering to Businesses" were organized by the National Productivity Center. National Productivity Center contributed to the first national ergonomics congress together with Istanbul Technical University in 1987. The Union of Chambers of Turkish Engineers and Architects, which takes care of human-machine relations and deals with ergonomics, organizes various congresses and symposiums (Köksüz, 2019).

Ergonomics has emerged as a response to design and operational problems depending on technological advances. Ergonomics, a hybrid discipline that emerged as a result of applied scientists coming together to solve interdisciplinary problems, owes its development to the same historical processes that created these disciplines (industrial engineering, occupational medicine, etc.). Ergonomics, which is related to basic sciences (psychology, anatomy, physiology, physics (especially mechanical and environmental physics), engineering, etc.), has also been influenced considerably by other emerging disciplines (industrial engineering, industrial design, systems theory, etc.) (Bridger, 2003).

2.5 Definition of Musculoskeletal Disorders

Occupational diseases are divided into four categories in the International Labour Organization (ILO) list of occupational diseases and Musculoskeletal Disorders (MSDs) are in the group of “occupational diseases originating from target organ systems” among occupational diseases (Çoker, 2019).

1. Occupational diseases arising from work activities
    - Diseases caused by chemical agents
    - Diseases caused by physical agents
    - Biological agents and infectious or parasitic diseases
2. Occupational diseases originating from target organ systems

- Respiratory diseases
- Skin diseases
- Musculoskeletal diseases
- Mental and behavioral diseases

3. Occupational cancers
4. Other diseases

Muscles, nerves, tendons, cartilage, ligaments, junctions, and discs (spine) are all affected by musculoskeletal disorders (Akay, Dağdeviren, & Kurt, 2003). Since the disorders related to the musculoskeletal system are generally exacerbated by the working environment, they are named as Work-related Musculoskeletal Disorders. The definition does not cover injuries caused by slipping, tripping, falling or similar accidents (Ma, Chablat, Bennis, & Zhang, 2009; Özel & Çetik, 2010).Different terminologies such as Cumulative Trauma Disorders (CTDs), Repetitive Strain Injury (RSI), Repeated Motions Injury (RMI), Occupational Overuse Disorders (OODs) are used to describe work-related musculoskeletal disorders problems (Özel & Çetik, 2010; Fang, Chen, Fang, & Xu, 2007). Skeletal and muscular system syndromes occur from ordinary body movements that human beings do in daily life, such as bending, straightening, holding, grasping, spinning and reaching out (Akay, Dağdeviren, & Kurt, 2003; Akpınar, Çakmakkaya, & Batur, 2018).

MSDs constitute 50% of work-related diseases (Tanır, Güzel, İşsever, Çalışkan Polat, 2013). According to ILO, every year, 250 million people in the world are exposed to occupational accidents and 160 million people are exposed to occupational diseases (Akpınar, Çakmakkaya, & Batur, 2018).

One of every four workers in Europe complains of low-back (24.7%) or general muscle pain (22.8%). The socio-economic consequences of musculoskeletal disorders in the European population cost an estimated €240 billion per year and are the most common ailments in Europe (Tanır, Güzel, İşsever, & Çalışkan Polat, 2013).

2.6 Causes of Musculoskeletal Disorders

Continuous repetitions, behaviors requiring force and rapid movements in business life make these movements harmful, and skeletal and muscular system syndromes are not an instant disorder but gradually developing traumas (Akay, Dağdeviren, & Kurt, 2003). MSDs can develop acutely or chronically depending on age, occupation, activity level and lifestyle (Felekoğlu & Taşan, 2017).

Fixed postures, continuous and repetitive movements, duration and frequency of work, strains in the body caused by improper postures, jobs that do not allow proper movement, and vibration lead to skeletal and muscular system syndromes (Akay, Dağdeviren, & Kurt, 2003). MSDs are generally not the result of a single event, but a cumulative type of injury. Often a case of musculoskeletal disorder is a combination of multiple risk factors rather than any factor that causes musculoskeletal disorder (Kolgiri, Hiremath, & Bansode, 2016; David, 2005).

Work-related MSDs, pain and fatigue disappear as a result of resting in the first stage and do not affect the performance of the employee. In the middle stage, pain and fatigue occur at the beginning of the work and performance decreasing is observed in repetitive tasks. In the advanced stage, rest does not relieve pain and performance decreasing is observed in the employee. The feeling of pain, which is the most frequently complained about by employees, is generally concentrated in areas such as the shoulder-neck region, upper extremities (hand and arm region), lower extremities (waist and leg region) (Akpınar, Çakmakkaya, & Batur, 2018).

The National Research Council and Institute of Medicine presented a model in the book they published on "Musculoskeletal Disorders and the Workplace" which is represented in Figure 2.1. This model illustrates that the three interacting workplace factors, external loads, organizational factors, and social context, can directly affect both biomechanical loading and outcomes such as pain and impairment (Habibi, Fereidan, Molla, & Pourabdian, 2008; Çoker, 2019).

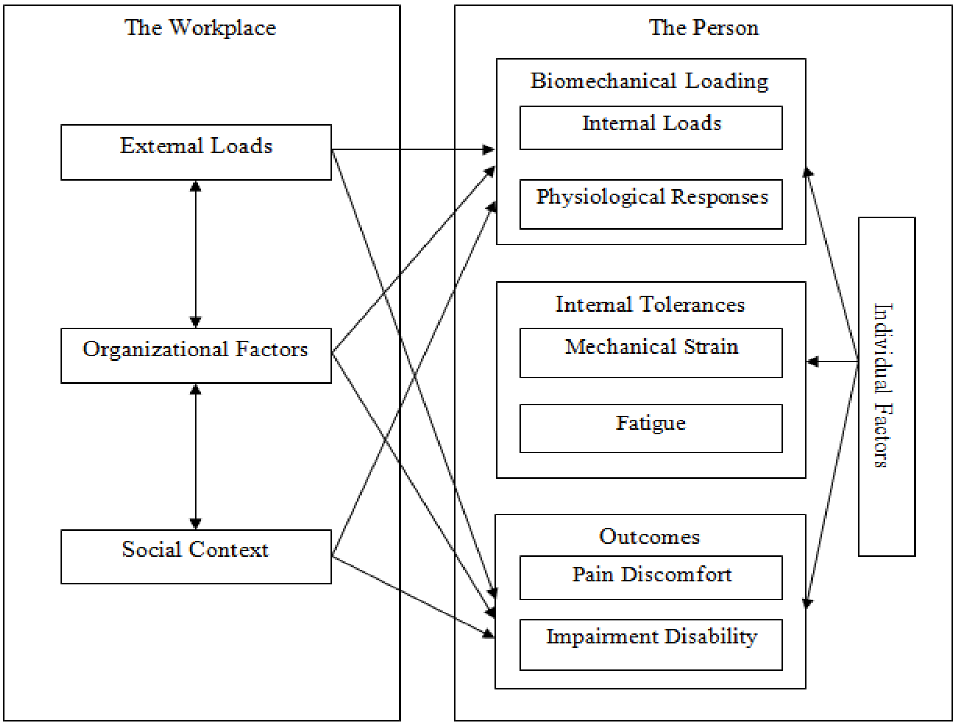

Figure 2.1 Conceptual model of various factors affecting the development of work-related musculoskeletal disorders (Habibi, Fereidan, Molla, & Pourabdian, 2008)

The most common MSDs in the industry are waist and back pain (myofascial pain syndrome, muscle strength imbalances, problems encountered especially in the lumbar region such as stress in the ligament), tendinitis, tenosynovitis, carpal tunnel syndrome, and tense neck syndrome (Akay, Dağdeviren, & Kurt, 2003).

2.7 Effects of Musculoskeletal Disorders

MSDs, one of the most common and important occupational health problems in the working population, have a significant impact on quality of life and cause a large economic burden in compensation costs and lost wages. They reduce productivity due to various reasons (sick leave, absenteeism, early retirement, etc.) and are also costly in terms of treatment (Erick & Smith, 2011). MSDs affect businesses and national economies as well as they cause discomfort to employees and loss of income (Tanır, Güzel, İşsever, & Polat, 2013).

Avoiding these disorders is largely possible with ergonomics interventions and ergonomic training aimed to reducing risks in the workplace (Kesiktaş & Özcan, 2015). The American National Institute for Occupational Safety and Health (NIOSH) states that musculoskeletal disorders can be reduced with well-designed ergonomics practices (Tanır, Güzel, İşsever, & Polat, 2013).

2.8 Studies in Countries Related to Musculoskeletal Disorders

The dramatic increase in the frequency and cost of occupational musculoskeletal disorders in industrialized countries has attracted the attention of employees, employers, health systems and insurance companies, and studies on risk factors, ergonomics program and treatment approaches have accelerated. In these countries, rapid and effective policies have been developed to prevent occupational musculoskeletal disorders. Public awareness about ergonomics has been created, and ergonomics training and ergonomic interventions have been rapidly implemented in workplaces (Kesiktaş & Özcan, 2015).

Although musculoskeletal diseases are accepted as an occupational disease by law in our country, studies on prevention of occupational musculoskeletal disorders are not known enough by employees, employers and physicians. Studies on the frequency of musculoskeletal disorders, risk factors, prevention training, effectiveness of ergonomic interventions, workday losses, insurance compensation and cost are not sufficient (Kesiktaş & Özcan, 2015).

In Turkey, there is no systematic ergonomic risk assessment approach used to evaluate and monitor work-related musculoskeletal disorders. Although the occupational health and safety works to be done with the workplace doctor and occupational safety specialist are regulated by the Occupational Health and Safety Law No. 6331 enacted in 2012 in Turkey, the lack of a systematic ergonomic risk assessment approach causes difficulties in many aspects of the ergonomic risk exposure assessment studies carried out by occupational safety experts (Felekoğlu & Taşan, 2017).

2.9 Ergonomic Risk Assessment in Work Environment

Ergonomic risk factors are events that, whether intentionally or inadvertently, can jeopardize the health, comfort, and welfare of people in their workplaces, or produce results that do not adhere to ergonomic principles. It is vital to be aware of the bad aspects of these situations and to raise awareness of them in order to take safeguards prior to seeking solutions to the difficulties (Kolgiri, Hiremath, & Bansode, 2016).

Exposure to risk factor is an early warning of more serious problems that may occur. Businesses and employees can decrease the risk of musculoskeletal disorders by looking at ways to identify and classify risk factors, as well as reducing the duration and frequency of exposure (Kolgiri, Hiremath, & Bansode, 2016).

Two employees who are equally exposed to the same risk factors are not affected in the same way. Even so, musculoskeletal diseases can be caused by a variety of reasons in the majority of workers. Awkward posture, force, repetition, vibration, static loading, contact stress, excessive heat, and noise are some of the most common ergonomic risk factors (Kolgiri, Hiremath, & Bansode, 2016).

Definition and evaluation of ergonomic risks in the workplace are required to prevent musculoskeletal disorders or their effects (Felekoğlu & Taşan, 2017).

2.10 Ergonomic Risks

Risk factors that cause musculoskeletal disorders can be divided into two main headings and they are presented in Figure 2.2. The first group is work-related risk factors and the second group is personal risk factors. Work-related risk factors include the characteristics of the load, the necessities of the job, the characteristics of the work environment and psychosocial factors (Felekoğlu & Taşan, 2017).

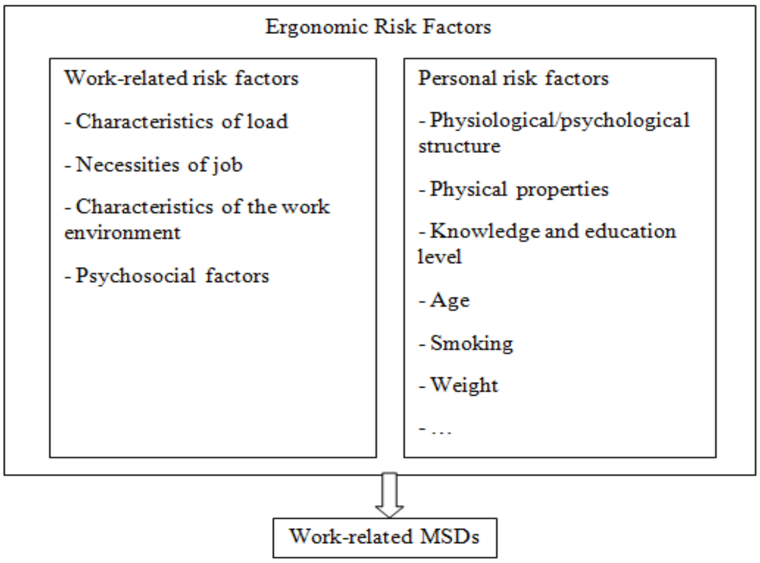

Figure 2.2 Ergonomic risk factors (Felekoğlu & Taşan, 2017)

The characteristics of the load such as weight, dimensions, balance, surface sensitivity, grip properties, position relative to the body can generate many risks for the employee. In addition, various risk factors occur due to the employee's job. Being a high-paced and tiring of work done, necessitating working in improper posture, insufficient rest periods, repetitive and vibrating movements can be given as a sample. The characteristics of the working environment are also among the work-related risk factors. Depending on the work done, the workplace is not at sufficient height and width, level differences on the work floor, obstacles in the working environment or the danger of falling/slipping, climatic conditions such as temperature, humidity and ventilation are examples of the characteristics of the working environment. Psychosocial factors such as administrative time pressure and mobbing may also constitute various risks (Felekoğlu & Taşan, 2017).

The second main topic, personal risk factors, stems from the individual characteristics of the employee. The physiological and psychological structure and physical characteristics of the employee are not sufficient for the job, the employee does not have sufficient knowledge, aging, smoking, excessive weight are some of these features. Also, the combined effects of the specified risk factors when they are seen together should be taken into account (Felekoğlu & Taşan, 2017).

2.11 Ergonomic Risk Assessment Methods

Correcting and improving of improper working postures is required in terms of employee health, performance and work productivity. Personal questionnaire methods, systematic observations and direct measurements are used to evaluate musculoskeletal disorders (Çiçek, Kazanç, & Kahya, 2018; Özel & Çetik, 2010; Özoğul, Çimen, & Kahya, 2018; David, 2005; Koç & Testik, 2016).

Personal questionnaire methods: Subjective questionnaires are used to assess the risk of MSDs and the Cornell Musculoskeletal Discomfort Questionnaire is the most preferred personal questionnaire method. These effective methods are low cost and can be applied to large-scale samples. However, the exposure level and variation of the methods have low validity.

Systematic observations: This method, which evaluates quantitatively the risk of MSDs, can be divided into two main headings: simple observational methods and advanced observational methods.

-Simple observational methods: NIOSH Lifting Equation, OWAS-Ovako Working Posture Analysis System), RULA-Rapid Upper Limb Assessment, REBA-Rapid Entire Body Assessment, OCRA-Occupational Repetitive Actions Index, QEC-Quick Exposure Check.

-Advanced observational methods: Ergo-Man, 3DSSPP, Jack, RAMSIS Model, Anybody Modeling System, SammieCad, Safework, Creo Manikin, HumanCAD, LifeMod can be given as examples.

These observational methods are the most preferred methods by the practitioners and are easier to use, less costly and more flexible.

Direct Measurement Methods: Electromyography (EMG), protractor, biomechanical analysis tools and optical tools are used to investigate employee postures and movements. This method shows the most accurate exposure level.

Direct measurement methods, which are costly compared to other methods, are not suitable for individual exposure assessment because they require significant resources and experts in large-scale studies.

CHAPTER THREE
LITERATURE REVIEW

In this section, studies on the evaluation and management of ergonomic risks are reviewed. There exists many scientific studies on the evaluation of ergonomic risks in different sectors, some of which are revealed below.

In their application, Sağıroğlu, Coşkun, & Erginel (2015), calculated REBA scores at the crank classification station, the valve plate ultrasonic bath washing station in a compressor operation. It was determined that the working positions have "moderate” level of ergonomic risk. The researchers underlined that it is necessary to change the location and angle of the crank basket, to adjust the seat height of the employee, to purchase a vacuum caliper crane for transportation to stations with heavy loads and a positionable lifting vehicle in order to reduce this score. It has also been exposed in the application that REBA scores can be reduced with some improvement studies.

Erdemir & Eldem (2019) evaluated ergonomic risks by using the REBA method in a metal casting factory. While applying the method, working conditions were simulated using CATIA V5 software and the posture angles of the employee were obtained. Ergonomic risks were reduced by making design changes and choosing the most suitable design.

Özay & Doğanbatır (2018) examined working postures of employees working in butcher, delicatessen, warehouse, grocery and cleaning sections of a company that carries out retail sales and has a supermarket chain in Turkey. The manual load lifting works of the workers were analyzed by the NIOSH lifting equation method, the working positions were analyzed by the REBA method, and the pushing and pulling works were analyzed by the Snook tables method. Suggestions were made to reduce the amount of load and asymmetry angle in product placement works to counters, to lift the boxes manually in the grocery section and to make mechanical changes in the counter in the butcher section. It is recommended to use forklifts or mechanical tools for transportation in the warehouse section, and to alternate between two employees for cleaning.

Erginel, Toptancı, & Acar (2018) analyzed the postures of the employees in a furniture factory by the fuzzy REBA method. Two different calculation methodologies were developed in the fuzzy REBA method. In the first calculation methodology, it was stated that the angular positions could not be determined clearly. In the second calculation methodology, all parameters consisting of angular position, optional motion, load/force, load grip/hold and motion scores were expressed as fuzzy numbers and included in the process. In the study, the risk assessment of sixty-three working postures in different stations, especially the risk assessment of two working postures, are exposed, and the improvements that can be made to reduce the risks are explained.

Özay & Özcan (2020) analyzed five different cleaning jobs and 12 working postures in two different cleaning workplaces by using REBA method. While four cleaning jobs were found to be of medium risk, one cleaning job was specified as of low risk. The average REBA scores were calculated as 4.7 in window wiping operations, 7 in floor wiping, 6.5 in floor sweeping, which were of moderate risk level. The REBA score was calculated as 3 in the floor wiping process, which was of low risk level. Ensuring rotation in the works, working of two people alternately in the works where the pushing and pulling force was intense, and regular use of rest breaks were presented as the improvements.

Gürleyen & Kahya (2018) were determined the average scores of 62 operations and 15 stations in the combi boiler assembly line of an enterprise by the REBA method. Fan grouping and third packing stations were found to be the stations having the highest risk level. The design of the assembly car, the location of the screens in the station and the packaging process, stacking of the finished combi boilers were exposed having high level of risk. Improvements were proposed for the processes, and a REBA analysis was made for the improved system, and the results were compared.

Zengin & Asal (2020) analyzed the posture of a total of 39 employees in four different tasks in building constructions by using REBA, OWAS and QEC ergonomic risk assessment methods. The results were analyzed with the Kruskal-Wallis test, and it was determined that the outputs of the QEC method differed from the other methods. In addition, the Scandinavian Musculoskeletal System Questionnaire was applied to 93 employees to create the body pain map of the employee. The body pain map exposed that the workers mostly have discomfort in the "waist" region. Among the four tasks examined, it was determined that the riskiest task in terms of exposure was "Brick/Plaster works", and "Scaffolding works" in terms of pain intensity. The researches also made some suggestions in the study to reduce the risks.

Aydın (2021) observed working postures at the order preparation workstation where manual lifting operations are carried out, and at the rayon workstation where service is provided to customers in a factory that sells meat and poultry products in the retail sector. NIOSH lifting equation model was used for manual lifting, and REBA method was employed for working postures in the rayon. It was concluded that the risk levels of the studies are high and that improvements are needed. At the order preparation workstation, the proposal was submitted to the factory that replacing the pallet from which the lift begins with an elevating pallet truck and the weight of the transported crates should be reduced from 20 kilograms to 15 kilograms. In the rayon area, the REBA score was initially calculated as 9, and as a result of the improvements made in this area, the REBA score was reduced to 3.In the study, recommendations were made for the lifting process and ergonomic risks were reduced with various improvements in the working positions.

Oral, Gönen, Karaoğlan, Tuncer, & Kundakçı (2018) assessed the processes in the production process of a feed plant. It was observed that the workers were working by crouching and bending during the assembly process. Working postures were analyzed with Muri and REBA, and working styles that would eliminate wasted time were evaluated. An automation system were designed in order to eliminate the working postures that force the employees. The aim was to increase employee welfare and satisfaction, to minimize the risk of making mistakes due to employees, to realize quality and productivity improvements and to increase competitiveness.

Alıcı, Ulusu, & Gündüz (2017) made risk assessment of pneumatic punching and pneumatic screwing works in a furniture manufacturing workshop. REBA, OWAS, OCRA, QEC and ManTRA methods were used considering static and dynamic postures and upper extremity positions. It was determined that the most appropriate ergonomic risk assessment method was the OCRA in cases where body parts such as hands, wrists, elbows and shoulders were used intensively in pneumatic punching and pneumatic screwing works and where technical movement frequency is high. By using OCRA method, a detailed evaluation was made by dividing the cycle time into stations and including each technical move in the analysis one by one.

Aydın, Çidem, & Kahya (2018) made risk assessments in the welding workshop of a metal industry-enterprise producing tractor cabins and agricultural machinery. Occupational health and safety risk with Fine-Kenney and Matrix Methods for each hazard especially welding gas and beam hazards, and ergonomic risk assessment with REBA method were carried out. It was stated that the protectors in the welding area for the beam need to be strengthened or replaced. In order to prevent the spread of welding gas, an appropriate hood was designed by the aspirator power and an economical and practical ventilation system was proposed. All high risks exposed were reduced to an acceptable level.

Okan & Kaya (2015) stated that the healthy saplings should be produced and brought to forest nurseries for afforestation studies. The main forest nursery works can be listed as planting, sewing, maintenance, moving, irrigation, dismantling and packaging. One of the most important processes is the process of moving the saplings to a large and suitable growing environment. This process consists of three stages: placing the material in the transport container, placing the saplings taken by cutting the roots into the transport container, and placing the soil in this container. The working postures of 70female workers working in the moving works in

Trabzon-Of forest nursery were examined with the REBA method and their risk levels were specified. It was determined that the employees are at moderate risk. In addition, ergonomic regulations regarding the workplace were required and employees should be made aware of their working postures.

Akar & Canbaz (2020) aimed to raise awareness in employees with orthopedic inadequacy by assessing the postures of employees with special needs, using REBA and RULA methods. It was stated in the study that the musculoskeletal disorders can be minimized by designing employees with special needs according to their anthropometric and physiological characteristics. A detailed evaluation was provided by REBA and RULA methods.

Gönen, Oral, Ocaktan, Karaoğlan, Cicibaş (2017) stated that, in order to designate the design criteria in assembly line designs, it is necessary to investigate which body parts will be taken into consideration as priority. Musculoskeletal disorders of workers in transformer manufacturer's assembly line were analyzed in the study by using the REBA and OWAS method. As a result of the analysis, the riskiest body parts were specified and an adjustable assembly table was designed in order to reduce the risks.

Sevimli, Ulusu, & Gündüz (2018) made ergonomic risk assessment of the employees in the packaging department, one of the production departments in the paddy factory, by using REBA and BAUA methods. Ergonomic analyzes of male and female employees at the workstations were carried out to remove the packaging balls from the pallet, take the balls to the packaging machine, insert the ball into the packaging machine, pack the packages, pack the boxes and place the pallets to the warehouse. Ergonomic risks were reduced by providing training on posture disorders, adding employees to stations with heavy workload, ensuring rotation in the workplace and adjusting the height of the turntable.

Adar & Delice (2020) stated that drivers working in urban public transportation experience both musculoskeletal disorders and mental pressure and fatigue due to their working postures. An integrated approach of AHP and COPRAS methods, which are multi-criteria decision making techniques, was used to compare drivers in terms of workload. Mental workload were specified using the NASA-TLX method, and physical workload were determined using the REBA method. Importance weights of the criteria were determined by the AHP method, and then by using the COPRAS method, 60 drivers were compared with. While the most important criteria in the study were determined as time pressure, it was observed that the neck part was more difficult than the other body parts. Precautions to be taken in order to reduce the workload of the drivers were presented in the study.

Kahya, Gülbandılar, & Gürleyen (2018) stated that arrangements according to ergonomic factors such as adjustable beds, lifting and carrying tools, and taking into account anthropometric measurements in the intensive care unit is so important for the prevention of musculoskeletal disorders. In their study, the strains experienced by healthcare personnel working in the neurology unit of a hospital during patient care and transportation were analyzed by using the REBA method. Eleven transactions were handled in the unit, and the REBA scores of these transactions ranged from two to ten. Alternative solutions were proposed in order to reduce the risk levels to an acceptable level. It was determined that the REBA score will decrease from 9 to 2 with the recommended patient lift for bed sheet arrangement and stretching, which has the highest risk score, and the REBA score will decrease from 9 to 3 with the slider bed sheet used for pulling the patient to the head of the bed.

CHAPTER FOUR
MATERIAL AND METHOD

Nowadays, although technological developments and automation seem to reduce the load on the human body, musculoskeletal disorders in developed and developing countries are among the top occupational diseases. As a result, economic losses occur and these losses affect not only individuals but also organizations and societies. Therefore, it is necessary to make risk analysis of the tasks and working postures and to determine the factors that cause physical burden, before these disturbances occur. Ergonomic risk assessment methods are used for this (Özel & Çetik, 2010).Observational methods such as OWAS (Ovako Working Posture Analysis System), RULA (Rapid Upper Limb Assessment) and REBA (Rapid Entire Body Assessment Method) are widely used to assess employee posture and identify ergonomic risks.

4.1 OWAS Method

OWAS is an observational and posture recording method that examines the employee posture during work and the appropriateness of this posture. It was developed in Finland by Ovako Steel Company. This method helps to make working postures suitable (Karhu, 1977; Çiçek, Kazanç, & Kahya, 2018; Özoğul, Çimen, & Kahya, 2018).

The method allows to determine inappropriate working postures and activities, to predict optimal work methods, to examine the compatibility between human and machine and to evaluate in terms of productivity, comfort and occupational health in the workplace (Akay, Dağdeviren, & Kurt, 2003).

In this method, working postures are classified and systematic studies are carried out on the design to eliminate the disturbing elements of the employee (Akay, Dağdeviren, & Kurt, 2003).

It has two hundred and fifty two (4x7x3x3) combinations of posture and load with four back postures, seven leg postures, three arm postures and three combinations of load situations that examine the weight of the load. The practitioner records the posture and load with the help of 4 digital codes by observing the employee during the work. Figure 4.1 illustrates the OWAS coding structure (Çiçek, Kazanç, & Kahya, 2018).

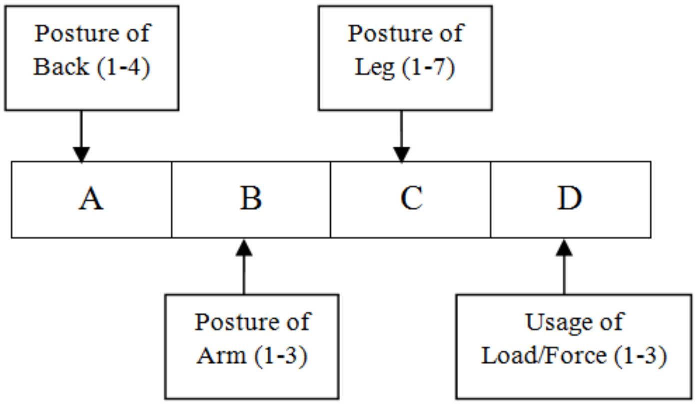

Figure 4.1 OWAS coding structure (Çiçek, Kazanç, & Kahya, 2018)

The detailed version of the OWAS coding structure is reported in Table 4.1.

Table 4.1 OWAS coding structure detail (Özcan & Yeğin, 2020)

	Back	Arm	Leg	Usage of Load/Strength
	A	B	C	D
1	Straight	If both arms are below shoulder level	Sitting	<10 kg
2	Oblique	If one arm is above shoulder level	Upright position: two-leg standing posture	10-20 kg
3	Turn over	If both arms are above shoulder level	Upright position: one leg standing posture	>20 kg
4	Twisted and Bent		Upright position: both legs in a bent position	
5			Upright position: one leg in a bent position	
6			Kneeling posture	
7			Walking position	

OWAS hazard levels are determined by using Table 4.2 after the calculations obtained according to the back, arm, leg and load/power use scores in Table 4.1.

Table 4.2 Determination of the OWAS hazard category

Back	Arms	1			2			3			4			5			6			7		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

In the next stage, the time spent in each body posture of the employee and the frequency of occurrence that posture are analyzed, and during the analysis. The postures are recorded and evaluated with fifteen seconds intervals in long-term activities and five seconds intervals in activities consisting of smaller time periods.

Then, it reaches OWAS action level by using action class matrix that includes back, arms, legs and load/force usage parameters. Action levels in the OWAS method change between 1 and 4 as reported in Table 4.3 (Çiçek, Kazanç, & Kahya, 2018).

Table 4.3 OWAS method score levels (Çiçek, Kazanç, & Kahya, 2018)

Score	Explanation
1	Ergonomic arrangement is not required
2	Ergonomic arrangement should be done soon
3	Ergonomic arrangement should be done as early as possible
4	Ergonomic arrangement should be done immediately

4.2 RULA Method

RULA method was developed by McAtamney and Corlett (1993). This method is one of the observation methods developed to reveal work-related upper limb disorders and used to analyze working positions (Dockrell et al., 2012). While determining the RULA score, it is evaluated in two separate groups, group A consisting of upper arm, lower arm and wrists, and group B consisting of neck, trunk and legs (Görgülü, 2019).

The steps of the RULA method are explained in the following (Karabacak, 2016).

Step 1: As illustrated in Figure 4.2, if the angle of the upper arm movements is between -20 degrees and 20 degrees, 1 point, less than -20 degrees, 2 points, between 20 degrees and 45 degrees, 2 points, between 45 degrees and 90 degrees, 3 points, and greater than 90 degrees, 4 points. If the shoulder is raised in the upper arm position; +1 if the upper arm is strained; +1 if the arm is supported or reclined; -1 point is given.

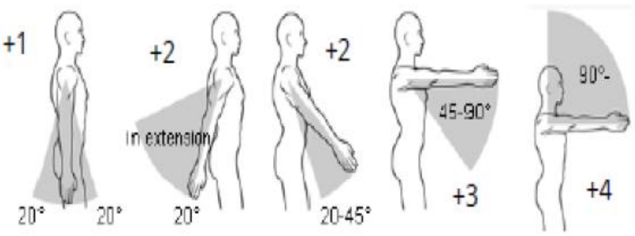

Figure 4.2 Upper arm scoring indicator (Kırcı, 2018)

Step 2: If the lower arm is between 60 degrees and 100 degrees as shown in Figure 4.3, +1 point is given. +2 points are given if there is an angle between 0-60 degrees or more than 100 degrees. If the arms open to the side during work, +1 is added and the lower arm score is calculated.

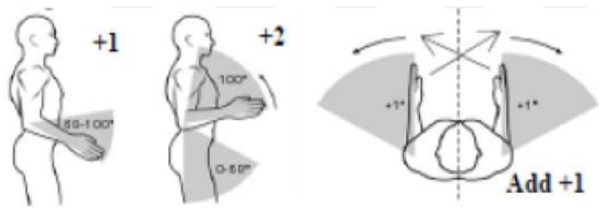

Figure 4.3 Lower arm scoring indicator (Kırcı, 2018)

Step 3: As indicated in Figure 4.4, 1 point is given if the wrist position is at 0 degrees, 2 points if it is between +15 degrees and -15 degrees, 3 points if it is more than +15 degrees, and 1 point is added if the wrist is bent from the midline.

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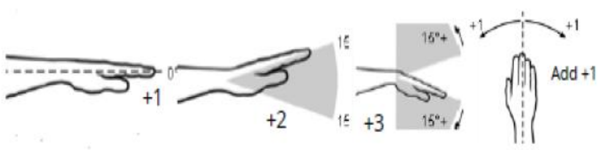

Figure 4.4 Wrist scoring indicator (Kırcı, 2018)

Step 4: As illustrated in Figure 4.5, 1 point is given if the angle of neck movements is between 0 degrees and 10 degrees, 2 points if it is between 10 degrees and 20 degrees, 3 points if it is more than 20 degrees, 4 points if it is less than -20 degrees, and if the neck rotates or if it bends sideways, 1 point is added.

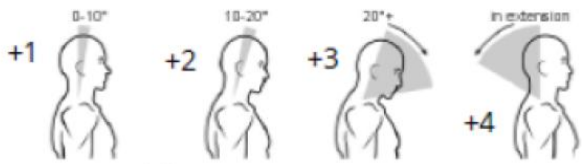

Figure 4.5 Neck scoring indicator (Kırcı, 2018)

Step 5: As demonstrated in Figure 4.6, the angle the trunk position makes with the center of gravity axis; it is given 1 point if it is 0 degrees, 2 points if it is between 0 degrees and 20 degrees, 3 points if it is between 20 degrees and 60 degrees, 4 points if it is greater than 60 degrees, and 1 point is added if the trunk rotates or bends to the side.

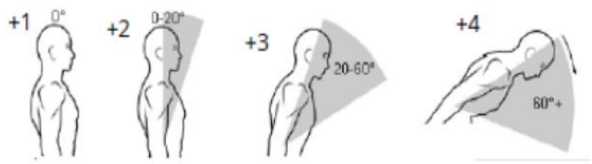

Figure 4.6 Trunk scoring indicator (Kırcı, 2018)

Step 6: If the feet and legs are equally supported by the balanced stance, 1 point is given, if not, 2 points are given.

Step 7: If there is a static posture longer than 10 minutes or muscle use more than 4 times per minute, the score is increased by 1 point.

Step 8: If there is no strength or if there is less than 2 kg of intermittent force loading, 0 point, if there is an intermittent force loading between 2 kg and 10 kg, 1 point, if there is a static or repetitive force loading between 2 kg and 10 kg, 2 points, if there is more than 10 kg of static or repetitive force loading, 3 points are given.

RULA score tables are reported in Tables 4.4 to 4.6.

Table 4.4 RULA score table A (Karabacak, 2016)

Upper Arm	Lower Arm	Wrist							
		1		2		3		4	
		Rotating Wrist		Rotating Wrist		Rotating Wrist		Rotating 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	2	3	3	3	4	4
2	1	2	2	2	3	3	3	4	4
	2	2	2	2	3	3	3	4	4
	3	2	3	3	3	3	4	4	5
3	1	2	3	3	3	4	4	5	5
	2	2	3	3	3	4	4	5	5
	3	2	3	3	4	4	4	5	5
4	1	3	4	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	3	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	7	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table 4.5 RULA score table B (Karabacak, 2016)

Neck Position Score	Trunk Position Score											
	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	2	1	2	2	3	3	4	4	4	4	4
2	1	2	2	2	3	4	4	5	5	5	5	5
3	2	2	2	3	3	4	4	5	5	5	6	6
4	2	3	2	3	3	4	4	5	5	6	6	6
5	3	4	4	4	4	5	5	6	6	6	6	6

Table 4.6 Table C where the grand final RULA score is calculated (Karabacak, 2016)

Table C		Final Score B						
		1	2	3	4	5	6	7
Final ScoreA	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

The RULA action table used in the interpretation of the calculated RULA final score is presented in Table 4.7.

Table 4.7 RULA action table (Karabacak, 2016)

Action Level	Score	Action
1	1 or 2	Working position is acceptable.
2	3 or 4	Examination is required, changes may be requested.
3	5 or 6	It should be examined and changed as soon as possible.
4	7	It should be examined and changed immediately.

4.3 REBA Method

REBA method was developed by Hignett and McAtamney (2000) (Akar & Canbaz, 2020). This method analyzes all parts of the body and determines the risk level of the analyzed working posture or movement quantitatively. The REBA method, which is based on observation and allows to examine both dynamic movements and fixed postures, ensure that detecting, preventing and taking necessary precautions of occupational skeletal musculoskeletal disorders (Akyol, 2017).

The schematic representation of the REBA score calculation is presented in Figure 4.7 (Hignett&McAtamney, 2000).

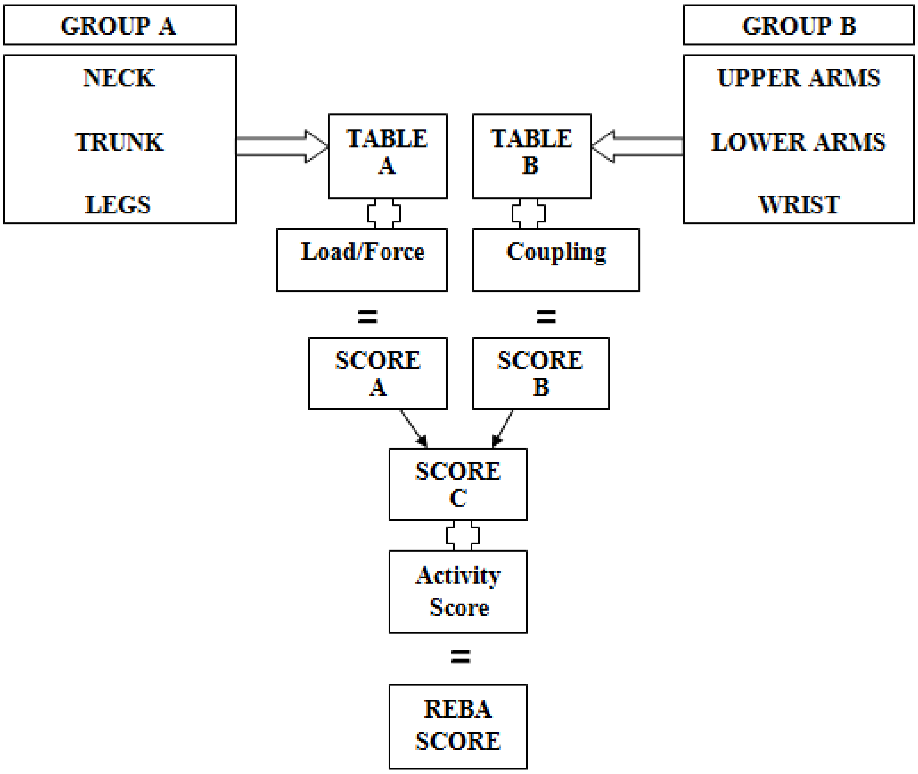

Figure 4.7 REBA score sheet (Hignett & McAtamney, 2000)

Group A: It evaluates the neck, trunk and leg parts of the body. After the scores of these body parts are calculated, they are marked in Table A and the score A is obtained where they intersect.

Neck: When calculating the score of the neck, scoring is made according to the vertical inward and outward bending of the neck. If there is a bending between 0° and 20°, 1 point is given, if there is a bend of more than 20°, 2 points are given. If the neck has a rotational movement, 1 point is added to the neck score.

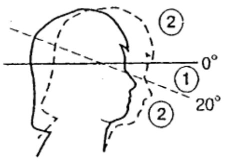

Figure 4.8 Neck positions of group A (Hignett & McAtamney, 2000)

Table 4.8 Neck score calculation (Hignett & McAtamney, 2000)

Movement	Score	Score Change
0°-20° Flexion	1	+1 if twisting or side flexed
>20°Flexion or Extension	2	

Trunk: The trunk score is calculated according to the trunk flexion angle. If the trunk has a rotational movement in horizontal plane, 1 point is added to the trunk score.

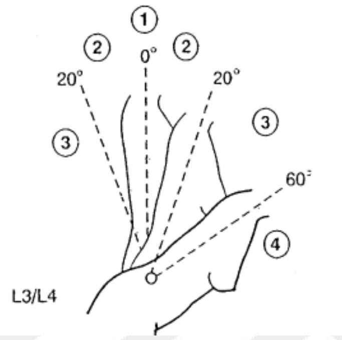

Figure 4.9 Trunk positions of group A (Hignett & McAtamney, 2000)

Table 4.9 Trunk score calculation (Hignett & McAtamney, 2000)

Movement	Score	Score Change
Upright	1	+1 if twisting or side flexed
0°-20° Flexion 0°-20° Extension	2	
20°-60° Flexion >20° Extension	3	
>60° Flexion	4	

Leg: Leg score is evaluated according to bilateral and unilateral weight bearing. If there is bending in the knees, 1 or 2 points are added to the leg score, depending on the situation.

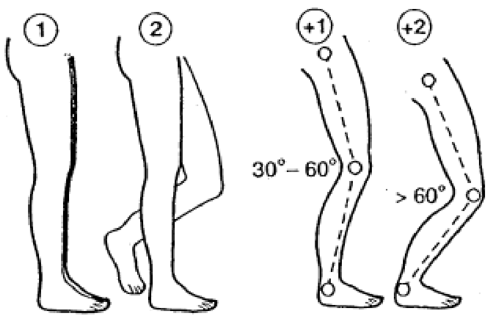

Figure 4.10 Leg positions of group A (Hignett & McAtamney, 2000)

Table 4.10 Leg score calculation (Hignett & McAtamney, 2000)

Movement	Score	Score Change
Bilateral weight bearing, walking or sitting	1	+1 if knee(s) between 30° and 60° Flexion +2 if knee(s) are >60° flexion (not for sitting)
Unilateral weight bearing or unstable posture	2	

A group score is obtained by marking the neck, trunk and leg scores on the A group score table.

Table 4.11 Score table of group A (Hignett & McAtamney, 2000)

		Neck											
		1				2				3			
		Legs				Legs				Legs			
		1	2	3	4	1	2	3	4	1	2	3	4
Trunk	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

By adding load/ force score to A group score, score A is obtained.

Table 4.12 Score table of load/force (Hignett & McAtamney, 2000)

Load/Force	Score	Score Change
<5 kg	0	+1 if sudden and rapid strength increase
5-10 kg	1	
>10 kg	2	

Group B: It evaluates the upper arm, lower arm and wrist parts of the body. After the scores of these body parts are calculated, they are marked in Table B and the score B is obtained where they intersect.

Upper arm: While calculating the upper arm score, scoring is made according to the vertical inward and outward bending of the neck. If there is a movement of rising from shoulder level or opening to the side in the upper arm, 1 point is added or subtracted from the score change depending on the situation.

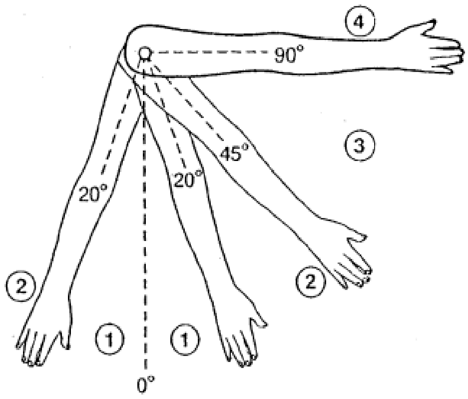

Figure 4.11 Upper arm positions of group B (Hignett & McAtamney, 2000)

Table 4.13 Upper arm score calculation (Hignett & McAtamney, 2000)

Movement	Score	Score Change
20° Extension to 20° Flexion	1	+1 if there is -abduction -rotation in the arm
20°-45° Flexion >20° Extension	2	
45°-90° Flexion	3	+1 if the shoulder is raised
>90° Flexion	4	-1 if leaning, supporting weight of arm or if posture is gravity assisted

Lower arm: The bends in the lower arms are scored according to whether they are between 60°-100° and less than 60° or greater than 100°.

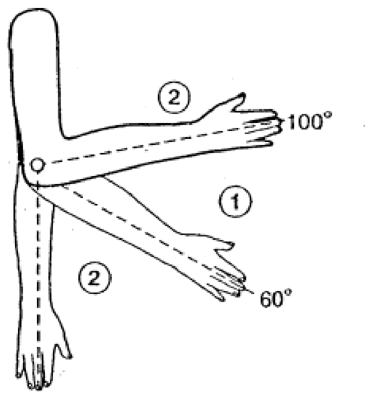

Figure 4.12 Lower arm positions of group B (Hignett & McAtamney, 2000)

Table 4.14 Lower arm score calculation (Hignett & McAtamney, 2000)

Movement	Score
60°-100° Flexion	1
<60° Flexion or >100° Flexion	2

Wrist: Bends less than 15° or more than 15° are calculated as 1 or 2 points. If there is a horizontal rotation in the wrist, 1 point is added to the score.

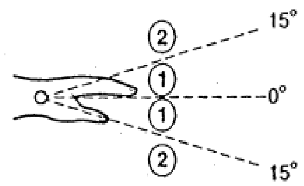

Figure 4.13 Wrist positions of group B (Hignett & McAtamney, 2000)

Table 4.15 Wrist score calculation (Hignett & McAtamney, 2000)

Movement	Score	Score Change
0°-15° Flexion/Extension	1	+1 if wrist is deviated or twisted
>15° Flexion/Extension	2	

B group score is obtained by marking upper arm, lower arm and wrist scores on the B group score table. By adding coupling score to the B group score, score B is reached.

Table 4.16 Score table of group B (Hignett & McAtamney, 2000)

		Lower Arm					
		1			2		
		Wrists			Wrists		
		1	2	3	1	2	3
Upper Arm	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	6
	4	4	5	5	4	5	5
	5	6	7	8	7	8	8
	6	6	7	8	8	9	9

Table 4.17 Score table of coupling (Hignett & McAtamney, 2000)

Rating	Explanation	Score
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	Possible although hand hold not acceptable	2
Unacceptable	Awkward unsafe grip, no handles Coupling is unacceptable using other parts of the body	3

After the scores A and B are calculated, score C is calculated at the intersection of the values as reported in Table 4.18. REBA score is reached by adding the activity score to the score C.

Table 4.18 Score table of group C (Hignett & McAtamney, 2000)

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

Table 4.19 Score table of activity (Hignett & McAtamney, 2000)

Activity	Score
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)	
Action causes rapid large range changes in postures or an unstable base	

The risk level calculated by the REBA method comments risk situation of the employee position and provides taking action correspondingly.

Table 4.20 Score table of activity (Hignett & McAtamney, 2000)

Action Level	REBA score	Risk Level	Action (including further assessment)
0	1	Negligible	None necessary
1	2-3	Low	May be necessary
2	4-7	Medium	Necessary
3	8-10	High	Necessary soon
4	11-15	Very high	Necessary NOW

As reported in Table 4.20, in case of the REBA score is less than 2, the risk level is negligible and action is not required. If the score is between 2 and 3, the risk level is low and action may be required. If the score is between 4 and 7, there is a moderate risk and action should be taken. If the score is between 8 and 10, there is a high level of risk and action needs to be taken soon. If the REBA score is between 11-15, the risk level is very high and action is required immediately.

CHAPTER FIVE
APPLICATION

5.1 General Information About the Company

In this study, the application was carried out in a manufacturing company located in Manisa producing marine materials. It has a rich product range and exports quite a lot to European and Asian countries. Manpower is essential for the company producing speargun, all components that generate the speargun (handle, skewer of speargun, pipe, rubber, head), fins, spare accessories (reel, belt, schnorkel, etc.), diving suits and accessories (socks, inner vests, back weight vest, wrist weight, etc.). The company has twenty white-collar employees and thirty-eight blue-collar employees (eleven employees in the textile department, twenty-seven employees in speargun department). Speargun department includes handle, skewer, rubber, accessories, fins (although they are not part of the speargun they are located in the same location) assembly and packaging stations, while textile section includes cutting, gluing, sewing and packaging stations.

The aim of this application is to investigate, determine and examine the risk factors of musculoskeletal disorders related to the position of employees in the company during their work by using ergonomic evaluation criteria. REBA method was employed to determine the risk levels. To this aim, images of several employees working in different departments of the company were recorded. There exist both male and female employees in the sample.

The REBA method was preferred in this thesis because it covers the whole body and is used in both dynamic and static positions. When we look at the general positions examined, it has been decided that the REBA method is suitable for this thesis.

5.2 REBA Application

In the company where the application was made, the textile and speargun sections were handled as two sections.

5.2.1 REBA Application of Textile Section in the Company

In Figure 5.1, the employee's position during the cutting area of the company's textile department was evaluated. The neck had flexion higher than 20 degrees, the trunk had flexion between 20 and 60 degrees, the upper arm had flexion between 45 and 90 degrees, the lower arm had flexion between 60 and 100 degrees, and the wrist had flexion between 0 and 15 degrees. Therefore, the employee does her duties with an inappropriate grip. The REBA score was determined as 9 based on these factors.

Department/Work	Textile/Cutting of fabric		
Score of Neck	2	Score Change	-
Score of Trunk	3	Score Change	-
Score of Legs	2	Score Change	-
Load/Force:	0		
Score of Upper Arm	3	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	-
Coupling	3		
Activity	+1		
REBA Score	**9**		

Figure 5.1 Cutting Section of Textile Department REBA score-1 (Personal archive, 2021)

Another cutting part involves neck flexion of greater than 20 degrees and trunk flexion of greater than 60 degrees, as well as neck and trunk flexion and rotation movements. Although the employee's hand grasp is adequate, it is not optimal. As reported in Figure 5.2, the REBA score is 9.

Department/Work	Textile/Cutting of fabric		
Score of Neck	2	Score Change	+1
Score of Trunk	4	Score Change	+1
Score of Legs	2	Score Change	-
Load/Force:	0		
Score of Upper Arm	2	Score Change	+1
Score of Lower Arm	2		
Score of Wrist	1	Score Change	-
Coupling	1		
Activity	+1		
REBA Score	**9**		

Figure 5.2 Cutting Section of Textile Department REBA score-2 (Personal archive, 2021)

As illustrated in Figure 5.3, the neck is exposed to more than 20 degrees of flexion in the textile department's gluing area. The trunk is straight and upright. She has a strong grasp of the situation. Then the REBA score of the working position is 5.

Department/Work	Textile/Preparation for gluing		
Score of Neck	2	Score Change	-
Score of Trunk	1	Score Change	-
Score of Legs	2	Score Change	-
Load/Force:	0		
Score of Upper Arm	2	Score Change	-
Score of Lower Arm	2		
Score of Wrist	2	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**5**		

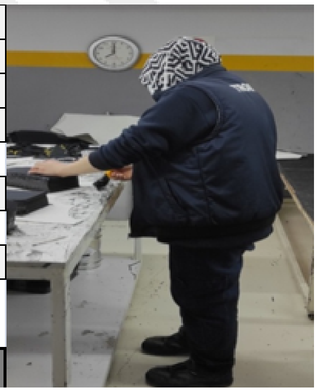

Figure 5.3 Gluing Section of Textile Department REBA score-3 (Personal archive, 2021)

In Figure 5.4, the employee is in a different position. Flexion and rotation movements are performed in the neck, trunk and wrist. As there is abduction in the upper arm, the upper arm score is increased by 1 point. Then the REBA score is calculated as 8.

Department/Work	Textile/Preparation for Gluing		
Score of Neck	2	Score Change	+1
Score of Trunk	1	Score Change	+1
Score of Legs	2	Score Change	-
Load/Force:	0		
Score of Upper Arm	2	Score Change	+1
Score of Lower Arm	2		
Score of Wrist	2	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**8**		

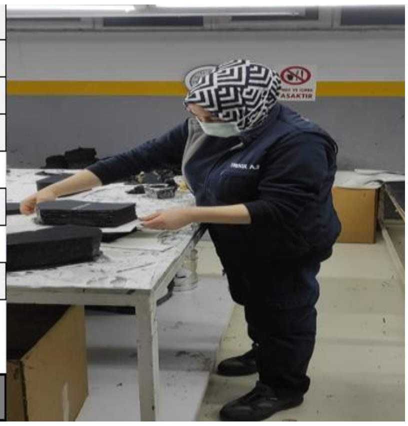

Figure 5.4 Gluing Section of Textile Department REBA score-4 (Personal archive, 2021)

In Figure 5.5, another employee's REBA score was calculated as 4 in the gluing section.

Department/Work	Textile/Preparation for gluing		
Score of Neck	2	Score Change	-
Score of Trunk	1	Score Change	-
Score of Legs	2	Score Change	-
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	2		
Score of Wrist	2	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**4**		

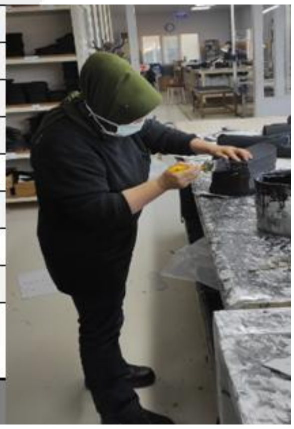

Figure 5.5 Gluing Section of Textile Department REBA score-5 (Personal archive, 2021)

The employee's position is determined by the job done on the sewing machine in Figure 5.6. Flexion of the neck ranges from 0 to 20 degrees. The trunk is straight and upright. The leg score of the employee that executes the sewing procedure while sitting has 1. The employee's REBA score is calculated as 2.

Department/Work	Textile/Sewing		
Score of Neck	1	Score Change	-
Score of Trunk	1	Score Change	-
Score of Legs	1	Score Change	-
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	2		
Score of Wrist	1	Score Change	-
Coupling	0		
Activity	+1		
REBA Score	**2**		

Figure 5.6 Sewing Section of Textile Department REBA score-6 (Personal archive, 2021)

The working position displayed in Figure 5.7 was obtained during the printing process of diving suits in the company's textile department. Flexion ranges from 0 to 20 degrees for both the neck and the trunk. The REBA score was calculated as 2 after computing the leg, upper arm, lower arm, and wrist scores.

Department/Work	Textile/Printing		
Score of Neck	1	Score Change	-
Score of Trunk	2	Score Change	-
Score of Legs	1	Score Change	-
Load/Force:	0		
Score of Upper Arm	2	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	-
Coupling	0		
Activity	+1		
REBA Score	**2**		

Figure 5.7 Printing Section of Textile Department REBA score-7 (Personal archive, 2021)

There exist flexion and rotational movements in the neck, trunk, and wrist, as well as abduction in the upper arm, in another posture of the employee. The REBA score was determined as 6 as illustrated in Figure 5.8.

Department/Work	Textile/Printing		
Score of Neck	1	Score Change	+1
Score of Trunk	2	Score Change	+1
Score of Legs	1	Score Change	-
Load/Force:	0		
Score of Upper Arm	2	Score Change	+1
Score of Lower Arm	2		
Score of Wrist	1	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**6**		

Figure 5.8 Printing Section of Textile Department REBA score-8 (Personal archive, 2021)

The employee’s neck in the packing department is flexed more than 20 degrees. The trunk is in an upright position and has an unsteady stance. Then the REBA score is calculated as 2 as illustrated in Figure 5.9.

Department/Work	Textile/Packing		
Score of Neck	2	Score Change	-
Score of Trunk	1	Score Change	-
Score of Legs	2	Score Change	-
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	-
Coupling	0		
Activity	+1		
REBA Score	**2**		

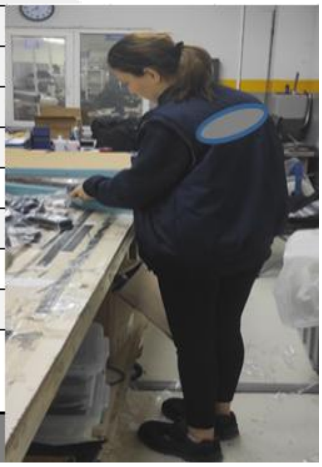

Figure 5.9 Packaging Section of Textile Department REBA score-9 (Personal archive, 2021)

The employee's position is illustrated on another sewing machine in Figure 5.10. The neck has more than 20 degrees of flexion, the trunk has between 20 and 60 degrees of flexion, and the upper arm has between 20 and 45 degrees of flexion. The REBA score in this case is 3.

Department/Work	Textile/Sewing		
Score of Neck	2	Score Change	-
Score of Trunk	3	Score Change	-
Score of Legs	1	Score Change	-
Load/Force:	0		
Score of Upper Arm	2	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	-
Coupling	0		
Activity	+1		
REBA Score	**3**		

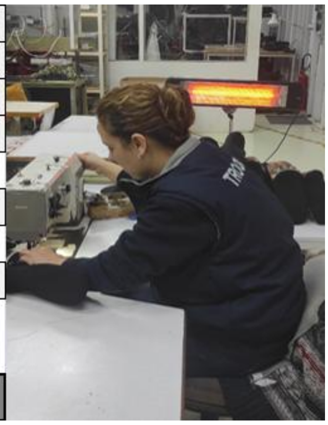

Figure 5.10 Sewing Section of Textile Department REBA score-10 (Personal archive, 2021)

In Figure 5.11, the REBA score was calculated as 2 in the packaging section.

Department/Work	Textile/Packing		
Score of Neck	1	Score Change	-
Score of Trunk	2	Score Change	-
Score of Legs	1	Score Change	-
Load/Force:	0		
Score of Upper Arm	2	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	-
Coupling	0		
Activity	+1		
REBA Score	**2**		

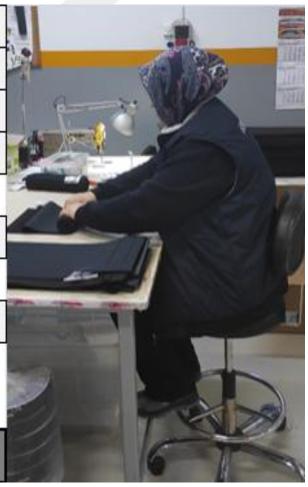

Figure 5.11 Packaging Section of Textile Department REBA score-11 (Personal archive, 2021)

5.2.2 REBA Application of Speargun Section in the Company

In Figure 5.12, the REBA score of working position of the employee working in the fins section is 3.

Department/Work	Fins/Assembling of fins		
Score of Neck	2	Score Change	-
Score of Trunk	2	Score Change	-
Score of Legs	1	Score Change	-
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	2		
Score of Wrist	1	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**3**		

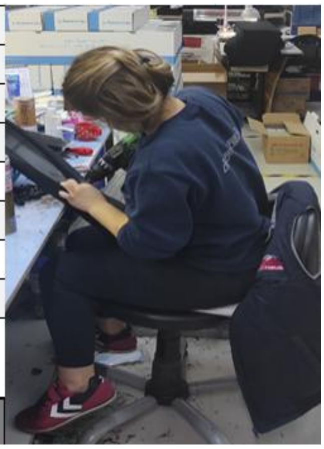

Figure 5.12 Fins Department REBA score-12 (Personal archive, 2021)

The employee's position in the accessory department of the firm throughout the shock rubber preparation process is assessed in Figure 5.13. Herein, the REBA score is 3.

Department/Work	Accessory/Preparation of shock rubber		
Score of Neck	2	Score Change	-
Score of Trunk	1	Score Change	-
Score of Legs	1	Score Change	+1
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**3**		

Figure 5.13 Accessory Section of Speargun Department REBA score-13 (Personal archive, 2021)

The position of the employee who assembles the reel is assessed in Figure 5.14. The employee's knees have flexion ranging from 30 to 60 degrees. The REBA score was calculated as 3.

Department/Work	Accessory/Assembling of reel		
Score of Neck	2	Score Change	-
Score of Trunk	2	Score Change	-
Score of Legs	1	Score Change	+1
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	-
Coupling	0		
Activity	+1		
REBA Score	**3**		

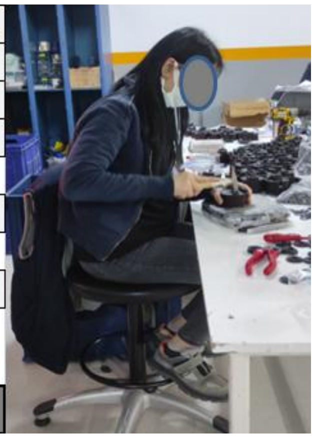

Figure 5.14 Accessory Section of Speargun Department REBA score-14 (Personal archive, 2021)

The employee's position during the rubber thread preparation is demonstrated in Figure 5.15. In the working position that conducts its task while sitting, the neck has more than 20 degrees of flexion and the trunk has between 0 and 20 degrees of flexion. Knee flexion is also available, ranging from 30 to 60 degrees. There is also a sideways flexing or rotational movement in the wrists. Herein, the REBA score was calculated as 4.

Department/Work	Rubber/Preparation of rubber thread		
Score of Neck	2	Score Change	-
Score of Trunk	2	Score Change	-
Score of Legs	1	Score Change	+1
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**4**		

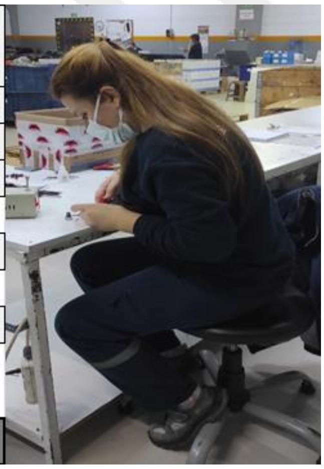

Figure 5.15 Rubber Section of Speargun Department REBA score-15 (Personal archive, 2021)

In Figure 5.16, the REBA score of working position obtained during the reel assembly process in the accessories section is calculated as 2.

Department/Work	Accessory/Assembling of reel		
Score of Neck	1	Score Change	-
Score of Trunk	1	Score Change	-
Score of Legs	1	Score Change	-
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**2**		

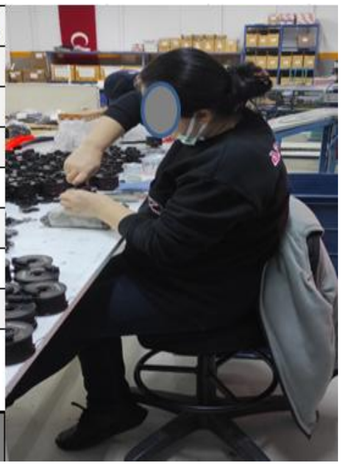

Figure 5.16 Accessory Section of Speargun Department REBA score-16 (Personal archive, 2021)

In the rubber cutting process, the employee's position is illustrated in Figure 5.17. There is a flexing and rotational movement in the trunk. More than 15 degrees of flexion can be seen on the wrist. The REBA score was calculated as 4.

Department/Work	Rubber/Cutting		
Score of Neck	2	Score Change	-
Score of Trunk	1	Score Change	+1
Score of Legs	2	Score Change	-
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	2		
Score of Wrist	2	Score Change	-
Coupling	0		
Activity	+1		
REBA Score	**4**		

Figure 5.17 Rubber Section of Speargun Department REBA score-17 (Personal archive, 2021)

In the rubber tacking process, the working position is illustrated in Figure 5.18. There is abduction of the upper arm. The REBA score was determined as 4.

Department/Work	Rubber/Rubber tacking		
Score of Neck	2	Score Change	+1
Score of Trunk	2	Score Change	-
Score of Legs	1	Score Change	-
Load/Force:	0		
Score of Upper Arm	2	Score Change	+1
Score of Lower Arm	1		
Score of Wrist	1	Score Change	-
Coupling	0		
Activity	+1		
REBA Score	**4**		

Figure 5.18 Rubber Section of Speargun Department REBA score-18 (Personal archive, 2021)

In the rubber shaving process, depicted in Figure 5.19, the REBA score of the working position is 3.

Department/Work	Rubber/Shaving of rubber		
Score of Neck	2	Score Change	-
Score of Trunk	1	Score Change	-
Score of Legs	2	Score Change	-
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**3**		

Figure 5.19 Rubber Section of Speargun Department REBA score-19 (Personal archive, 2021)

The employee's position in the skewer section is illustrated in Figure 5.20. Herein, the REBA score was determined as 3.

Department/Work	Skewer of Speargun/Cutting		
Score of Neck	2	Score Change	-
Score of Trunk	1	Score Change	-
Score of Legs	2	Score Change	-
Load/Force:	0		
Score of Upper Arm	2	Score Change	-
Score of Lower Arm	2		
Score of Wrist	1	Score Change	-
Coupling	0		
Activity	+1		
REBA Score	**3**		

Figure 5.20 Skewer Section of Speargun Department REBA score-20 (Personal archive, 2021)

In Figure 5.21, the REBA score of working position in speargun packing section is 3.

Department/Work	Speargun/Packing of speargun		
Score of Neck	1	Score Change	-
Score of Trunk	1	Score Change	-
Score of Legs	1	Score Change	+1
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**3**		

Figure 5.21 Speargun Packing Section of Speargun Department REBA score-21 (Personal archive, 2021)

The REBA score for the employee in Figure 5.22 who perform his work while sitting in the handle assembly section was determined as 4. His knees are flexed between 30 and 60 degrees.

Department/Work	Handle/Assembling of handle		
Score of Neck	2	Score Change	-
Score of Trunk	2	Score Change	-
Score of Legs	1	Score Change	+1
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**4**		

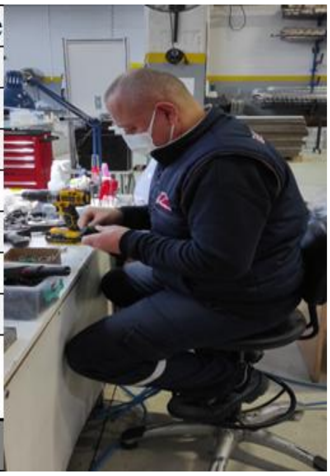

Figure 5.22 Handle Section of Speargun Department REBA score-22 (Personal archive, 2021)

The employee's position during the assembly of the mechanism in the handle section is presented in Figure 5.23. For the working position with lateral flexion or rotation of the wrists, the REBA score was determined as 2.

Department/Work	Handle/Preparation of mechanism of handle		
Score of Neck	1	Score Change	-
Score of Trunk	1	Score Change	-
Score of Legs	1	Score Change	-
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	1		
Score of Wrist	1	Score Change	+1
Coupling	0		
Activity	+1		
REBA Score	**2**		

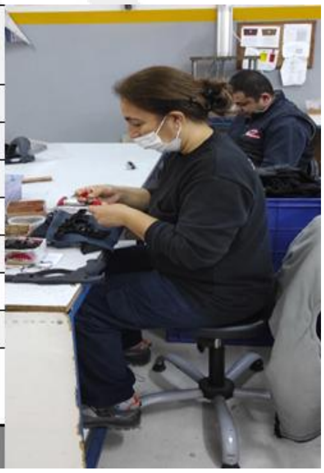

Figure 5.23 Handle Section of Speargun Department REBA score-23 (Personal archive, 2021)

The neck has more than 20 degrees of flexion, while the trunk has 20 degrees to 60 degrees of flexion in Figure 5.24.Then, the employee's REBA score is 4.

Department/Work	Speargun/Assembling of handle,pipe and head		
Score of Neck	2	Score Change	-
Score of Trunk	3	Score Change	-
Score of Legs	2	Score Change	-
Load/Force:	0		
Score of Upper Arm	1	Score Change	-
Score of Lower Arm	2		
Score of Wrist	1	Score Change	-
Coupling	0		
Activity	+1		
REBA Score	**4**		

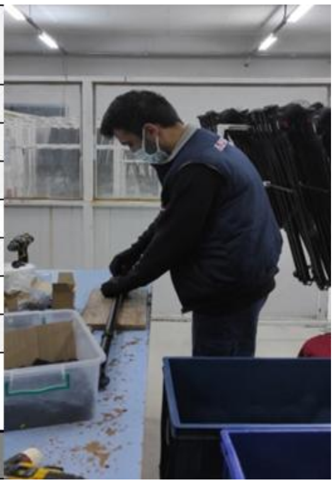

Figure 5.24 Speargun Assembling Section of Speargun Department REBA score-24 (Personal archive, 2021)

In the speargun assembly section, the working position during the alignment process is indicated. Flexion of the upper arm ranges from 45 to 90 degrees. The employee's REBA score was calculated as 5 as illustrated in Figure 5.25.

Department/Work	Speargun/Assembling of Speargun		
Score of Neck	1	Score Change	-
Score of Trunk	1	Score Change	-
Score of Legs	2	Score Change	-
Load/Force:	0		
Score of Upper Arm	3	Score Change	-
Score of Lower Arm	2		
Score of Wrist	1	Score Change	-
Coupling	0		
Activity	+1		
REBA Score	**5**		

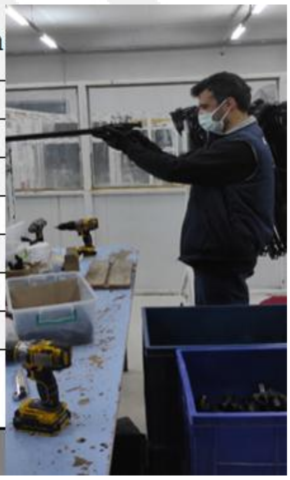

Figure 5.25 Speargun Assembling Section of Speargun Department REBA score-25 (Personal archive, 2021)

5.2.3 Suggestions for Interventions

The REBA scores of the employees are reported together in Table 5.1

Table 5.1 REBA Scores and Risk Levels of the Employees

Department	Section	REBA Score	Risk Level
Textile	Cutting	9	High
	Cutting	9	High
	Gluing	5	Medium
	Gluing	8	High
	Gluing	4	Medium
	Sewing	2	Low
	Sewing	3	Low
	Printing	6	Medium
	Printing	2	Low
	Packing	2	Low
	Packing	2	Low
Speargun	Accessory	3	Low
	Accessory	3	Low
	Accessory	3	Low
	Accessory	2	Low
	Rubber	4	Medium
	Rubber	4	Medium
	Rubber	4	Medium
	Rubber	3	Low
	Skewer	3	Low
	Packing	3	Low
	Handle	4	Medium
	Handle	2	Low
	Assembling of Speargun	4	Medium
	Assembling of Speargun	5	Medium

The application revealed that employees have high risk in the cutting section of the textile department of the company, while they have medium risk in the gluing and printing section, and medium risk in the rubber, handle and speargun assembly sections of the speargun department. Therefore, precautions should be taken immediately, especially for the employees with high risk level, and care must be taken for the employees with medium risk level.

Adjustable tables can be used for those working in the cutting and gluing department of the textile department, which has a high-risk working position.

Administrative controls such as employee rotation, more job variety and increased rest breaks can be provided.

In the departments of textile and speargun departments with medium and low risk working positions, personal protective equipment that relaxes the posture can be used to reduce the risk level. The possibility of musculoskeletal disorders can be reduced by allowing the employee to rest with regular intervals for repetitive tasks.

When we examine for all risks, workstations should be redesigned considering ergonomic risk factors. Providing ergonomics training and exercises in the workplace is important for a healthy working life. It can also be effective to offer employees incentives for ergonomic habits if the recommendations are met with resistance. When all these improvements are made, it is predicted that the REBA scores of the working positions will decrease.

CHAPTER SIX

CONCLUSION

The main purpose of ergonomics studies is to increase work efficiency by protecting the physical and mental health of employees. Inappropriate working postures in the workplace cause work-related musculoskeletal disorders. Accordingly, the analysis of ergonomic risks related to the working positions of the employees is very important.

In this study, ergonomic analyzes of the working positions of the employees in different units of a manufacturing company were made and work-related musculoskeletal disorders were evaluated. The REBA method, which is one of the commonly used ergonomic risk assessment methods, was employed. Twenty-five working positions in the company have been examined. It was determined that three employees have high risk level while nine of them have medium risk. Precautions should be taken immediately, especially for working postures with a high risk level, and care must be taken for working postures with a medium risk level.

In the light of the findings obtained, suggestions were reported to the managers of the company to increase the health and safety of the employees, as well as the work efficiency and quality. The work stations should redesigned by considering ergonomic risk factors. If repetitive tasks are performed, the possibility of musculoskeletal disorders can be reduced by allowing the employee to rest at certain intervals. Rotation may be recommended for this case. In order to reduce the risk level, personal protective equipment that relaxes the posture can be used. Providing ergonomics training and exercises in the workplace are important for a healthy work life.

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