

DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

**APPLICATION OF ERGONOMIC RISK
ASSESSMENT APPROACHES BY USING GROUP
DECISION ANALYSIS IN SERVICE SECTOR**

by
Elif GÜLER

November, 2018
İZMİR

APPLICATION OF ERGONOMIC RISK ASSESSMENT APPROACHES BY USING GROUP DECISION ANALYSIS IN SERVICE SECTOR

**A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University
In Partial Fulfillment of the Requirements for the Degree of Master of Science
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**by
Elif GÜLER**

**November, 2018
İZMİR**

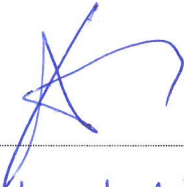
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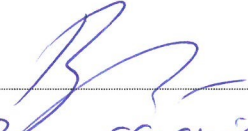
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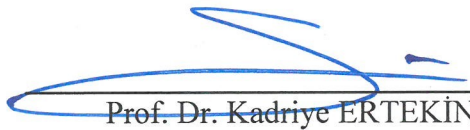
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APPLICATION OF ERGONOMIC RISK ASSESSMENT APPROACHES BY USING GROUP DECISION ANALYSIS IN SERVICE SECTOR

ABSTRACT

Risk assessment is important for prevention of occupational musculoskeletal system disorders (OMSD). Using of existing risk assessment methods in literature alone are not sufficient to identify work's risk level. Determining risk level of work using methods assessing one type risk doesn't give accurate and reliable results. The physical and psychosocial ergonomic risks are key factor in formation of OSD. However, there isn't any research that integrates physical and psychosocial risks to assess them. Physical ergonomic risk assessment methods alone or psychosocial ergonomic risk assessment methods alone do not provide sufficient information on hazard dimensions of ergonomic risks. To determine risk level of work, firstly all risks affecting that work should be determined. It is very important to establish common evaluation according to identified risks and to determine risk level of work in terms of reliability of evaluation. The purpose of this study is to propose an integrated ergonomic risk assessment methodology (IERAMCA) by using outcomes of physical ergonomic risk assessment methods and psychosocial ergonomic risk assessment methods. These outcomes are weighted with multi-criteria decision analysis methods. Providing an integrated assessment and applying IERAMCA to obtain main causes of OSD of laboratory staff in the blood center of a university hospital is aimed. The laboratory staff is likely to experience work-related musculoskeletal disorders due to the frequent occurrence of ergonomic risks in laboratory. According to results of study, works in laboratory is in medium risk group. According to this result, intervention recommendations have been developed.

Keywords: Occupational musculoskeletal system diseases, ergonomics, risk assessment, laboratory staff

SERVİS SEKTÖRÜNDE GRUP KARAR ANALİZİ YAKLAŞIMI İLE ERGONOMİK RİSK DEĞERLENDİRMESİNİN UYGULAMASI

ÖZ

Mesleki kas iskelet sistemi rahatsızlıklarının önlenmesi için risk değerlendirmesi çok önemlidir. Mevcut risk değerlendirme yöntemlerinin kullanımı, işin risk düzeyini belirlemek için yeterli değildir. Bir işin risk düzeyini belirlerken tek bir risk türünü değerlendiren yöntemlerin kullanılması doğru ve güvenilir sonuçlar vermemektedir. Mesleki kas iskelet sistemi hastalıklarının oluşumunda fiziksel ve psikososyal ergonomik riskler oldukça etkilidir. Ancak, bu iki farklı risk grubunu aynı anda değerlendirmek için birleştiren bir yöntem yoktur. Tek başına fiziksel ergonomik risk değerlendirme yöntemleri veya sadece psikososyal ergonomik risk değerlendirme yöntemleri ergonomik risklerin tehlike boyutları hakkında yeterli bilgi vermemektedir. Bir işin risk düzeyini belirlemek için öncelikle bu işi etkileyen riskler belirlenmelidir. Belirlenen risklere göre ortak bir değerlendirme yapmak ve çalışmanın risk düzeyini belirlemek değerlendirmenin güvenilirliği açısından çok önemlidir. Bu çalışmanın amacı, fiziksel ergonomik risk değerlendirme yöntemlerinin ve psikososyal ergonomik risk değerlendirme yöntemlerinin sonuçlarını kullanarak entegre bir ergonomik risk değerlendirme metodolojisi (IERAMCA) önermektir. Bu sonuçlar çok kriterli karar analiz yöntemleri ile ağırlıklandırılmıştır. Bir üniversite hastanesinin kan merkezindeki laboratuvar personelinin mesleki kas iskelet sistemi bozukluklarının temel nedenlerini elde etmek için entegre bir değerlendirme sağlanması ve bu entegre ergonomik risk değerlendirme metodolojisinin uygulanması amaçlanmıştır. Laboratuvar ortamında ergonomik risklerin sık görülmesi nedeniyle laboratuvar personelinin işle ilgili kas-iskelet sistemi bozukluklarına maruz kalması olasıdır. Çalışmanın sonuçlarına göre, laboratuvardaki işler genel olarak orta risk grubundadır. Bu sonuca göre müdahale önerileri geliştirilmiştir.

Anahtar kelimeler: Mesleki kas-iskelet sistemi hastalıkları, ergonomi, risk değerlendirmesi, laboratuvar personeli

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CHAPTER ONE

INTRODUCTION

With the rapid development of technology, businesses have been dragged into a ruthless competitive environment due to the rapidly increasing consumption rate. Businesses have begun to increase production speeds to keep up with this brutal competitive environment. With the rapid increase in the production rate, the pressure on the employees has begun to increase considerably. This situation causes adverse effects on employee productivity and employee health. The concept of ergonomics comes into play in order to eliminate or minimize these adverse effects. It can be said that one of the biggest factors affecting employee productivity is the factors that affect the harmony between employee and working environment (Gutnick, 2007).

All efforts to eliminate or limit the physical and psychosocial stresses of working and living conditions and the efforts of people to cope with this stress, the investigation of the measures to ensure harmony, and the compulsive and negative effects, are within the field of ergonomics (Griffiths, 2006). The ergonomic work environment is the work environment designed considering the elements of ergonomic design. Working in an ergonomic work environment affects work efficiency and employee health positively. Repeated exposure to improper and inadequate body posture and movements reveals musculoskeletal disorders. This situation causes serious loss of material and spirituality in the case of employees, employers and the state. The prevention of musculoskeletal disorders is very important in terms of increasing the morale, motivation and performance of the employee while protecting the health of the employee throughout his / her working life. Therefore, preventing the occurrence of occupational musculoskeletal system diseases contributes to the country's industry and the economy (EU-OSHA [European Agency for Safety and Health at Work], 2018).

Musculoskeletal disorders that occur due to the pain, movement restriction and injuries. These disorders occur with the effect of physical and psychosocial risks. These diseases are called occupational musculoskeletal disorders if they develop depending on the work. Repetitive, forced movements at work, use of the body in bad

positions, and ergonomic inefficiencies are highly effective in the formation of these diseases (Schuchmann,1996; Özcan,2002).

Occupational musculoskeletal system disorders are caused by repeated movements such as bending, gripping, rotating, gripping, tightening and lengthening. Tendons, nerves, other soft tissues and muscles are at levels that cause discomfort due to repetitive movements (Bernacki et al.,1999). The mentioned movements are the movements we often make in everyday life and are not really dangerous. These movements become dangerous when they are carried out at work due to incomplete repetitions, inadequate working speed, and insufficient time between two movements (CCOHS, 2014).

Musculoskeletal system disorders are classified as diseases of the waist, neck, and upper limb (wrist, hand, elbow and shoulder) (Bernacki et al.,1999). Musculoskeletal system disorders due to waist and back pain, neck retention, muscle strain and hurt, neck swelling, waist sickness, carpal tunnel syndrome, strained neck syndrome and muscle strength imbalances are the main complaints (Bernacki et al.,1999; NIOSH,1997).

Today, the incidence of musculoskeletal disorders is quite high in many different occupational diseases. According to the Labor Force Survey conducted in 2007, musculoskeletal disorders constitute more than 50% of occupational illnesses. (EUMUSC, n.d.)

The cost of musculoskeletal system diseases can be examined by dividing into three main groups: These costs are indirect, direct and invisible costs. Direct costs include medical attendance costs such as medical examination, diagnostic tests, hospitalization, drug use. Indirect costs are the cost of loss of labor that occurs on report days and the cost of performance decline. Invisible costs are the reduction of quality of life, physical and social functions. (Lubeck, 2003)

Occupational musculoskeletal disorders are among the most important health problems of employees and reduce work productivity. It is possible to prevent these adverse effects of occupational musculoskeletal system disorders. (Felekoğlu & Taşan,

2017) All necessary precautions should be taken in the work environment to reduce and prevent these diseases.

Relations between working life and human health have been considered for many years only as problems of workers in industrial business. However, there are risks to each sector's employees (Hendrick, 2006). Contrary to what is believed, the service sector employees are exposed to many ergonomic risks that cause musculoskeletal disorders, just like manufacturing sector. One of the areas of work having significant ergonomic risks in terms of occupational health and safety is the area of health care. In the health care sector, especially hospitals have many risk factors that affect health of the employees (Janowitz et al., 2006).

Hospitals have a wide range of business lines. In any workplace except hospitals, transport of heavy materials, processing with chemical substances, use of radioactive materials, biological risks, cutting-drilling tools are not combined. In addition to all these factors, health workers exposed to intense pace of work, long-term and continuous operation, non-ergonomic working environment and work stress. Because of these factors, health of the health care employees is affected adversely. The likelihood of health workers facing occupational risks varies according to occupation and the department in which they work (World Health Organization, 2002; Di Martino, 2003). The working environment is also very important for occupational musculoskeletal disorders. Factors such as wet flooring, high steps, irregularities on the floor lead to accidents such as crashing, slip, fall, buckling (Layne & Pollack, 2004).

One of the areas of healthcare work area that is at high risk of developing occupational musculoskeletal system illness is the laboratories. Laboratory workers are exposed to many hazardous substances and ergonomic risks due to their nature. Laboratory-related risk factors are not different from any office or industry (ASSTSAS, 2014) Factors influencing the formation of musculoskeletal injuries in laboratory workers: repetitive movements, inappropriate posture, use of excessive force (Mitchell, 2010b). Some of the ergonomic risk factors around the laboratory environment are pipetting, microscope, laboratory benches, microtome, biological safety booths (ASSTSAS, 2014).

As mentioned above, laboratory employees are one of the occupational groups experiencing occupational musculoskeletal system disorders. Because the laboratory environment includes occupational accidents and biological, ergonomic, chemical, physical and psychosocial risks. Factors such as bad posture positions, repetitive movements, improper postures, time pressure, pressure from precision of work and ergonomically inappropriate workplace affect the health of laboratory workers in the negative direction and these factors particularly cause the formation of occupational musculoskeletal system disease. Despite the fact that laboratory staff are exposed to so many high-impact risks, there are not enough studies in this regard.

1.1 Aim of the Study

The physical and psychosocial ergonomic risks are quite influential in the formation of OMSD. There are many physical and psychosocial ergonomic risk assessment tools. However, there is no method that merge these two different risk groups to assess them at the same time. Physical ergonomic risk assessment methods alone or psychosocial ergonomic risk assessment methods alone do not provide sufficient information on hazard dimensions of ergonomic risks.

The purpose of this study is to propose an integrated ergonomic risk assessment methodology by weighting outcomes of physical ergonomic risk assessment methods and psychosocial ergonomic risk assessment methods with multi-criteria decision analysis methods and provide an integrated evaluation and to apply this integrated ergonomic risk assessment methodology to achieve the main causes of occupational musculoskeletal disorders of laboratory staff in the blood center of a university hospital.

1.2 Outline of the Study

This study consists of seven chapters. Chapter 1 presents an introduction about the study. In this section, the purpose of the work and outline of the study are mentioned. This section includes general information about the thesis study. Chapter 2 contains comprehensive information on ergonomics. This section generally mentions ergonomics concept, occupational musculoskeletal system disorders, risk factors for

occupational musculoskeletal diseases, disease types and prevention of these diseases. In Chapter 3, ergonomic risk assessment methods are introduced. There is literature review of ergonomic risk assessment in this chapter. Chapter 4 is about multi-criteria decision-making methods. In this chapter, the reason of using multi criteria decision making method in this study is explained. In Chapter 5, the proposed methodology in this study is explained. Chapter 6 presents real-life application of the phases of the proposed methodology.

Chapter 6 explains the phases of implementation in a university hospital's laboratory. Firstly, preliminary investigation is carried out in the application phase. Job analysis is carried out according to the results of the preliminary investigation. Evaluation methods to be applied according to job analysis results are selected. In Chapter 7, a general summary of the work is presented. The contributions of the study are mentioned.

CHAPTER TWO

ERGONOMICS

2.1 Ergonomics Concept

Ergonomics word derived from Greek. It is formed by the fusion of these two words: ergon (work) and nomos (laws). According to International Ergonomics Association ergonomics is a science dealing with figuring out the interplays between the elements of the system and people and it is also an expertise that performs data, principles, design methods and theory so as to optimize all system performance and human welfare. In figure 2.1, it is described as follows: the evaluation and design of five elements (International Ergonomic Association, 2018)

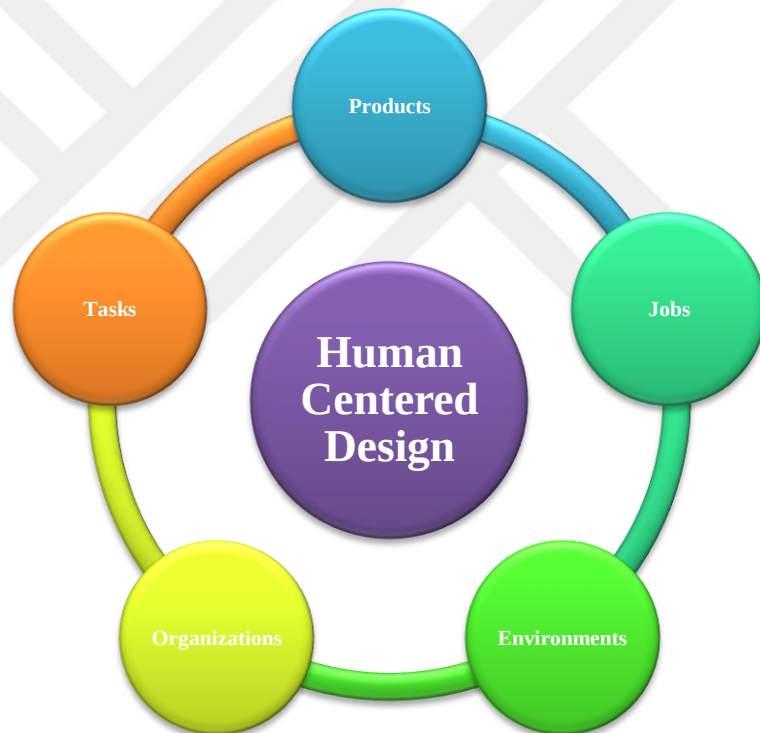


Figure 2.1 Ergonomics concept (International Ergonomic Association, 2018)

There are three basic areas of expertise in the ergonomics. The areas of expertise in the discipline of ergonomics are in a broad way as follows (International Ergonomic Association, 2018):

- **Physical Ergonomics** is related to human anthropometric, physiological, anatomical and biomechanical features. Some of the issues within the physical

ergonomics are as follows: occupational musculoskeletal disorders, workplace arrangement, working stances, recurring movements etc. (International Ergonomic Association, 2018)

- **Cognitive Ergonomics** interested in mental processes such as memory, judgment, motor response and perception as the relationship between humans and other elements of the system is affected by these factors. Some of the issues within the cognitive ergonomics are as follows: decision making process, stress and education study, spiritual workload, technical expertise, human-computer mutual effect etc. (International Ergonomic Association, 2018)
- **Organizational Ergonomics** is related to the optimal situation of sociotechnical systems according to organizational process, structure and policies. Some of the issues within the organizational ergonomics are as follows: planning of work and working times, communication within the organization, team resource management, quality management, working with collaboration etc. (International Ergonomic Association, 2018)

2.2 Occupational Musculoskeletal System Disorders (OMSD)

People have a certain ability to move, a way to create energy in their muscles in the musculoskeletal system and this system has the ability to perceive the environment. So, there must be a balance between the tasks of the employees and the basic characteristics of a person in the workplace. If the ergonomic conditions in the workplace are poor, the balance and harmony that is likely to be affected is affected negatively. Today occupational musculoskeletal disorders are very common problem in many businesses because of employees exposure to various risks in workplaces where have poor ergonomic conditions for employees. Work efficiency reductions, workday losses, fatigue and injuries are most often caused by musculoskeletal disorders. (Daneshmandi et al., 2017)

Musculoskeletal system disorders can be expressed as discomforts and injuries in muscles, tendons, ligaments, joints and nerves. The most important factors that affect musculoskeletal disorders in work places are listed as follows: repetitive and

compulsive movements in workplaces, inappropriate body postures, ergonomically inappropriate work tools and workstations designs etc. Musculoskeletal disorders associated with these factors in the workplace are considered to be related to occupational musculoskeletal disorders. (OSHA, 2000)

2.2.1 OMSD Types

Occupational musculoskeletal disorders are clinically divided into three phases (CCOHS, 2014):

- **Early Stage:** Pain and fatigue in the body part, which has discomfort during work, passes when you are at rest and does not affect your work performance.
- **Medium Stage:** Pain and fatigue occur during the onset of the work and last overnight. There is also a reduction in performance in repetitive jobs.
- **Advanced stage:** The pain does not go by rest, it can prevent sleep, and the reduction in performance in this phase is obvious.

Luttmann et al. (2003) noted that the following diseases among occupational musculoskeletal disorders are common in various body parts:

- **Shoulder-Neck Diseases:** Biceps tendinitis, shoulder-acromioclavicular joint osteoarthritis, thoracic outlet syndrome, cervicobrachial pain syndrome, cervical spondylosis, rotator cuff disease etc.
- **Upper extremity diseases:** Arm, elbow and ankle tendonitis, Hand-arm vibration related diseases, nerve compression-related diseases, carpal tunnel syndrome and etc.
- **Waist and lower extremity diseases:** Waist pain, disc hernia, etc.

Some movements in the occupational musculoskeletal system cause pain (Bilir, 2007). The main of these pain-causing movements and the pain areas are shown on Table 2.1 (Bilir, 2007).

Table 2.1 Some movements that cause pain in the occupational musculoskeletal system (Bilir, 2007)

Movement Type	Pain Region
Repeated excessive strain on the wrist in the horizontal-vertical direction. Movement of your fingers in case of strain.	Wrist and hand thenar
Repetitive twisting and strain on the wrist. Wrist and folding in forearm.	Wrist
To reach on shoulder level. To reach back behind the trunk. To reach a distant point in a compelling way.	Neck and shoulder (DeQuervain's disease)
Repetitive bending of the hand and tightening strongly.	Thumb root
Long-lasting flexion on the shoulder. To stretch arms over shoulder level. To carry a load on the shoulder.	Bluntness and swelling in the hands (Thoracic outlet syndrome)

2.2.2 OMSD Risk Factors

Mert (2014) stated in her study that the role of work-related physical and psychosocial factors in the formation of OMSD has been scientifically proven. In the formation of these disorders, not only the work carried out in the workplace but also the activities undertaken outside the workplace are influenced.

Risk factors that can cause OMSD are divided into three groups: work-related, personal and environmental (Özcan, 2011):

1. Work-related risk factors:

- a. Physical Factors;
 - Repetitive movements,
 - Force,
 - Unsuitable body postures,
 - The same posture for a long time,
 - Vibration.
- b. Psychosocial risk factors;
 - Job dissatisfaction,
 - Monotony,
 - Time pressure,

- Inadequate colleague support,
- Inadequate organizational factors such as lack of breakdowns

2. Personal risk factors:

- a. Aging,
- b. Fitness,
- c. Having been ill before,
- d. Cigaret.
- e. Excess weight.

3. Environmental risk factors:

- a. Temperature,
- b. Moisture,
- c. Noise,
- d. Ventilation,
- e. Lighting,
- f. Slippery of the floor.

Many studies have been conducted on the risk factors that play a role in the formation of occupational musculoskeletal system disorders. Some of the studies on this subject are explained below. According to Ayanoğlu (2007), occupational factors related to musculoskeletal disorders and accelerating the discomfort process are ergonomic risk factors. Ergonomic risk factors can be examined under 3 main headings according to this study. These 3 main factors are psychological (cognitive overload, psychosocial effects, organizational influences), environmental (noise, temperature and humidity, lighting, vibration, chemicals) and physical factors (repetition, inappropriate postures, static posture, excessive force, jamming).

Türkkan (2009) has stated that the factors affecting those musculoskeletal diseases are divided into three groups. These three groups are ergonomic, psychosocial and individual factors (Türkkan, 2009). There is a relationship between work-related musculoskeletal disorders and ergonomic and psychosocial factors (Hales & Bernard, 1996; Toomingas et al., 1997). It is very important to consider individual factors as well as physical and psychosocial factors in understanding these diseases (Andersen

et al., 2002). Ergonomic and psychosocial factors have not been elaborated in this study.

In Hoozemans et al. (1998)'s study, risk factors affecting musculoskeletal disorders associated with pushing and pulling are investigated. The risk factors examined are investigated from four different perspectives: psychophysics, physiology, epidemiology and biomechanics. It is determined that pushing and pulling are related to lower back pain according to the epidemiological studies examined. The risk factors affecting musculoskeletal disorders are divided into three groups: working condition, working method and employee personal characteristics.

In Hoogendoorn et al. (2000)'s study, it is examined that the psychosocial factors related to work and private life whether constitutes a risk factor for back pain. Observational studies on this subject is examined for this purpose. Psychosocial risks have been given great importance among the risk factors affecting the back pain the majority of studies examined. But in the studies examined there is no systematic approach to this important finding. Bibliographic investigation of several databases is carried out and eleven cohort and two case control studies are examined in this study. lack of social support and job dissatisfaction are identified as risk factors affecting back pain.

Buckle & Devereux (2002) have conducted a research on occupational musculoskeletal system disorders in the neck and upper limbs. Research has been conducted on scientific data and the opinion of the union bodies, state institutions and experts. They have examined the need for classification and diagnostic methods for the evaluation of neck and upper extremity (NUE) musculoskeletal disorders. In the European Union NUE musculoskeletal disorders are a major problem in terms of patient health, productivity and related costs. They noted that the relationship between work performance and the occurrence of NUE musculoskeletal disorders is clear.

Punnett & Wegman (2004) have done research on occupational musculoskeletal system disorders. The risk factors affecting musculoskeletal disorders are listed as follows; physical ergonomic features of work, repetitive motion, work pace, vibration and unsuitable body postures. Many methods are used to detect occupational

musculoskeletal system disorders. These methods are working self-report methods, researcher observations and direct measurement methods. But there is no standardized exposure measurements and therefore no comparison can be made between studies.

In Costa & Vieira (2010)'s study, risk factors affecting the occurrence of occupational musculoskeletal disorders have been investigated. Four different databases have been used to investigate occupational musculoskeletal system disorders. Risk factors affecting musculoskeletal disorders are separated according to the affected body part, level of evidence and type of risk. Risk factor types are categorized as follows: psychosocial, biomechanical, or individual. Also, level of evidence is categorized as follows: strong, plausible, or inadequate evidence.

2.2.3 Protection from OMSD

Organizations can prevent the formation of musculoskeletal diseases by carrying out effective ergonomic programs. These ergonomics programs will be applied successfully if employers and employees take on the responsibilities. When everyone fulfills their responsibilities, it may be possible to prevent musculoskeletal system diseases by controlling the risks identified, and especially the ergonomic risks, as a result of risk analysis and evaluation. One of the most important factors in preventing musculoskeletal diseases is education. Protection from OMSD is possible with ergonomics training and reorganization of work conditions. Employees are aware of the ergonomic risk factors through the training programs organized at the workplace and employees are actively involved in their protection. Management of musculoskeletal system diseases in a planned manner reduces the risk of diseases. (Önal, 2007)

CHAPTER THREE

LITERATURE REVIEW: ERGONOMIC RISK ASSESSMENT METHODS

Only physical and psychosocial risks within the scope of this study are analyzed. For this reason, only the evaluation methods developed for these risks are included in this section. There are many methods in literature to evaluate physical and psychosocial risk factors. Methods that evaluate physical risk factors are divided into three as subjective judgement, systematic observations and direct measurements methods. Psychosocial risk assessment methods are based on subjective judgement. Figure 3.1 shows the categorization of methods of assessing work-related risk factors. This chapter includes a literature review of physical and psychosocial risk assessment methods. The studies of the last 24 years (1994-2018) of these methods have been examined and some of them have been presented.

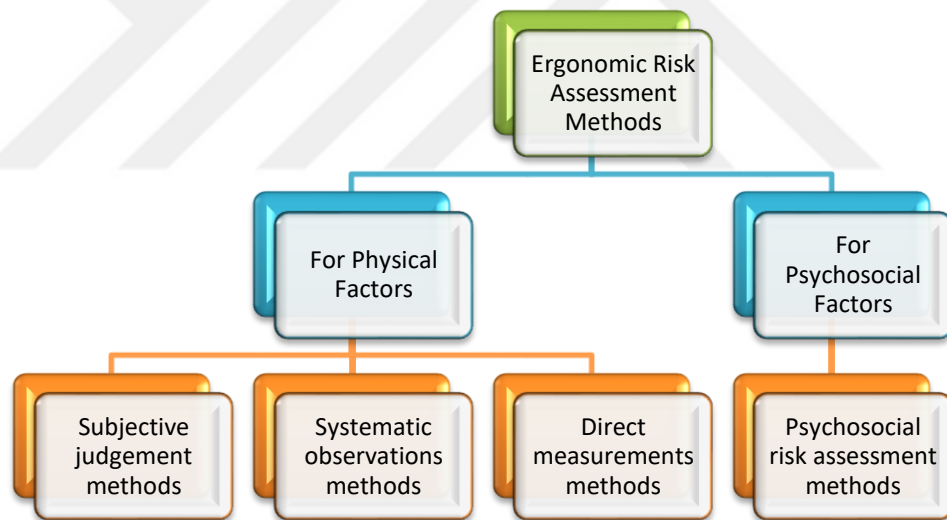


Figure 3.1 Ergonomic risk assessment methods

The economic dimension of musculoskeletal disorders in the workplace affects not only individuals but also organizations and societies as a whole (Meenaxi & Sudha, 2012). Therefore, precautions should be taken before these discomforts occur, risk analyzes of tasks should be performed and risk factors should be determined (SLIC, 2004). Musculoskeletal disorders are usually caused by problems in work

environment, so risk assessment tools are used to identify the factors that influence disease development (David, 2005).

The role of psychosocial stressors, physical factors (such as repetitive, compulsive movements, weight lifting, use of incorrect body mechanics and vibration) and individual factors has been proven in the development of occupational musculoskeletal disorders. Various techniques have been developed to assess changes in exposure and exposure to risks in musculoskeletal diseases. These techniques include mainly observational measurements, instrumental or direct methods, and self-reported subjective judgement methods. (David, 2005)

Exposure assessment techniques are classified into three categories (Village et al., 2008; David, 2005):

1. Subjective judgement,
2. Systematic observations,
3. Direct measurements.

Among these methods, the most commonly used are observational methods. Because observational methods have some important advantages over other methods. The most important advantages of observational methods are as follows: simple application, quick reply, postural evaluation opportunity without division of work. Observational methods are also well suited for jobs where the body posture has been stable for a long time. Although observational methods have some advantages over other methods, they also have some disadvantages. Some of these disadvantages have been described. The optimum number of observations for low and high repetitive tasks is not clearly defined. In the employee's physical workload assessments, the observer makes a subjective assessment and this assessment is not sufficient. The observation method is less sensitive than evaluating dynamic works. They are more suitable to evaluate static work. (David, 2005)

David (2005) classified subjective judgement, systematic observations and direct measurements methods, explained them and listed the methods belonging to these classes.

3.1 Subjective Judgement Methods

The main advantage of subjective assessment methods is that they are cost-effective methods and can be applied to large-scale samples (Koç & Testik, 2016). One of the disadvantages of this methods is that it is doubtful that the absolute measurement of the risk of developing musculoskeletal disorders associated with work is determined by these methods. Therefore, the use of other methods in situations where the risk is thought to be excessive gives more detailed and reliable results. (David, 2005)

There are many self-reported methods for evaluating exposures. Questionnaires and checklists are used as a subjective risk assessment method. The most commonly used in the literature from these methods are listed below (David, 2005). Some of these questionnaires: The Cornell Musculoskeletal Discomfort Questionnaire (Hedge et al., 1999), Nordic Musculoskeletal Questionnaire (Kuorinka et al., 1987), Dutch Musculoskeletal Questionnaire (Hildebrandt et al., 2001), Body Discomfort Map (Corlett & Bishop, 1976), Rating of Perceived Exertion (Borg, 1970), Swedish Occupational Fatigue Inventory (Ahsberg, 1997) etc.

- **Cornell Musculoskeletal Discomfort Questionnaire (CMDQ)** was developed by Hedge et al. (1999). It examines musculoskeletal disorders in 12 body parts (20 body parts-right/left side). These parts are neck, shoulder, upper back, upper arm, lower back, forearm, wrist, hip/buttocks, thigh, knee, lower leg, foot. CMDQ wants to mark the frequency of feeling of pain, pang, discomfort in the last one week in these 20 body parts. If felt, it should also be marked for discomfort and interference of work. This method will be explained in detail in Chapter 6.
- **Nordic Musculoskeletal Questionnaire (NMQ)** is a questionnaire providing information on the onset, prevalence, and consequence of musculoskeletal pain in nine body parts (neck, shoulders, back, elbows, wrists / hands, waist, hips / thighs, knees, ankles/feet) (Kuorinka et al., 1987).

- **Dutch Musculoskeletal Discomfort Questionnaire (DMQ)** examines the working conditions that may create musculoskeletal system risks separately for walking, standing, sitting and uncomfortable postures. In the Dutch Musculoskeletal Questionnaire, questions are asked about the workload, risk-taking of working conditions and musculoskeletal disorders of the body parts. (Hildebrandt et al., 2001)
- **Body Discomfort Map (BDM)** is a subjective symptom research tool that directly assesses employees' discomfort experiences in different body parts. These parts are neck, shoulders, upper back, upper arms, mid back, lower arms, lower back, buttocks, thighs and legs. (Corlett & Bishop, 1976)
- **Rating of Perceived Exertion (RPE)** is used to measure the level of physical activity intensity. How tired the body during the work is expressed perceived exertion. Perceived exertion is based on heart rate, sweating breathing rate and muscle fatigue during the physical activity. (Borg, 1970)
- **Swedish Occupational Fatigue Inventory (SOFI)** was mentioned about the features of this method and implemented in Johansson et al., 2008 study. This method was developed to contribute to figuring out the concept of tiredness by researching subjective qualities of tiredness in employees in different professions (Åhsberg et al., 1997, Åhsberg, 2000).

In investigating musculoskeletal system disorders (MSD) from the above-mentioned questionnaires which are frequently preferred today: CMDQ, Dutch Musculoskeletal Questionnaire and Nordic Musculoskeletal Questionnaire. The studies of these methods and other methods are explained in detail in the following Table 3.1. 14 studies have been examined in total. The following tables contain the following information about the articles: participants, number studied (n), using methods, applied analyzes and study findings. The studies that have been performed in the last 16 years. In some of these articles only methods that detect existing musculoskeletal disorders were used. A number of studies investigated the effects of occupational stress on musculoskeletal system disorders. In these papers in addition to self-reported musculoskeletal disorders methods, some occupational stress checklists

or psychosocial risk assessment tools were used. Also, some studies used available health records to detect musculoskeletal disorders. These records can be accessed from the workplace health and safety unit.

Table 3.1 Recent literature review subjective judgement methods

Article	Study Sample	Methods	Analyzes	Findings
Joksimovic et al., 2002	Personnel of a public transport establishment (n=316)	A MSD questionnaire together with 3 psychosocial risk assessment scales	Prevalence, Univariate-bivariate analyses, Mann–Whitney U test, chi-square test, multivariate logistic regression analyses	70.4% backpain, 60.1% neck pain and 52.9% shoulder pain 33.4%, hip 24.3% upper extremities 36.2%, lower extremities 46.2%, physical job demand, 27.4% low control at work, 15.1% imbalance between effort and reward
Picavet & Hazes, 2003	Adults (n=3664)	A MSD checklist	Prevalence, Cochran-Mantel-Haenszel test	41% of the men and 48% of the women experienced MSD. The most common MSD are tendinitis or capsulitis and osteoarthritis of the knee.
Menzel et al., 2004	Nursing personnel (n=113)	CMDQ	Linear regression analysis, Variance analysis, Chi-square analysis, Games Howell t-test,	Moderately severe musculoskeletal complaints were recorded in 62% of employees. There is a relationship between waist and knee pain.
Choobineh et al., 2007	Hand-woven carpet industry employees (n=1439)	NMQ, Together with a systematic observation-based method (i.e. RULA)	Chi-square test, Multiple logistic regression analysis,	Body parts that are the most damaged in terms of MSD: shoulders (47.8%), wrists/hands (38.2%), knees (34.6%), upper back (37.7%), neck (35.2%) and lower back (45.2%), 81% of the employees have suffered from MSD within the past 12 months.
KirtigandhaSalwe et al., 2011	Hospital cleaners (n=106)	NMQ, Available health records	Prevalence	Injury rate of hospital cleaners: %34.9, Symptoms of MSD: lower back 49%, right wrist 43%, ankle, left knee and left wrist 35%, right knee 34%, right shoulder 25%.

Table 3.1 continues

Sethi et al., 2011	Computer workers (n=100)	CMDQ, Together with a systematic observation-based method and a psychosocial risk assessment scale	ANOVA, Chi square analysis, multivariate discriminant functional analysis	The CMDQ score is max for workers in the overweight group according to body mass index and minimum for underweight workers. Psychosocial risk assessment scale score is found high in employees with high body mass index.
Kuru et al., 2011	Adults (n=250)	CMDQ, Together with a MSD questionnaire	Prevalence, Descriptive Analysis	7.2% of the participants had no pain, 92.8% had musculoskeletal system pain. Ranking of the incidence of pain according to body parts: lower back, neck, back, shoulder, upperarm, forearm, wrist, hip, upper leg, knee, lower leg.
Eatough et al., 2012	Full-time employees (n=277)	NMQ, Together with 6 psychosocial risk assessment scales	TCALIS procedure, Factor analysis, Partial Mediation Test, Full Mediation Model Testing, Descriptive analysis	Each psychosocial risk factor is associated with at least one musculoskeletal system disease, safety leadership is related to wrist/hand lower back symptoms are related to role conflict and safety leadership.
Jansen et al., 2012	Female assembly workers (n=37)	CMDQ	Descriptive Analysis, Prevalence	Risk regions most affected by musculoskeletal discomforts: neck (44%), lower back (19.7%), right wrist (15%).
Magdy et al., 2013	Secondary School Saudi Female Teachers (n=280)	NMQ, Together with a MSD questionnaire	Prevalence, Chi-square test, Regression analysis	Musculoskeletal pain: 79.17%. According to body parts: lower back 63.8%, shoulder 45.4%, neck 42.1%, leg (40.0%), wrist 16.2%, elbow 10.0%
Widanarko et al., 2014	Workers (n=3003)	NMQ, Together with a psychosocial risk assessment scale	Multivariable logistic regression, Prevalence, Hosmer Lemeshow test	Neck/shoulder symptoms:58%, arm/elbow symptoms: 24%, wrist symptoms: 30%. The percentage of reduced activities because of Neck/shoulder symptoms:15%, arm/elbow symptoms:7% wrist symptoms:7%

Table 3.1 continues

Abledu et al., 2014	Urban Taxi Drivers (n=210)	NMQ	Multiple logistic regression analysis, Prevalence, Univariate logistic regression	The percentage of MSD according to the body parts: lower back pain (34.3%), knee pain (10.0%), neck pain (15.2%), upper back pain (16.7%), hip/thigh pain (2.9%), ankle/feet pain (2.4%), shoulder pain (11.0%), elbow pain (4.8%), wrist/hand pain (1.9%)
Calik et al., 2014	Students using computers (n=871)	CMDQ	Mann-Whitney U test, Chi square test, Spearman's Correlation Analysis, Spearman's Correlation Analysis, Descriptive Analysis, Spearman's Correlation Analysis.	Risk regions most affected by musculoskeletal discomforts: neck (21.6%), lower back (19.3%), upper back (16.3%).
Rafie et al., 2015	Dentists (n=130)	NMQ, Together with a systematic observation-based method (i.e. RULA)	Prevalence, T-test, Chi-squared test, Logistic regression	82.8% of subjects are at high risk interms of MSD, Musculoskeletal pains: neck (55.9%) and the shoulder (43.8%)
Dockrell et al., 2015	Primary school children (n=529)	Body discomfort map, Together with a behavioural screening questionnaire for children	Prevalence, Pearson's Chi-square test, Fisher's Exact Test, T-test, Logistic regression, Descriptive analysis	Most of the discomfort associated with the schoolbag is related to the shoulders and back. Tables of association of psychosocial, physical and individual factors with school bag -related back and shoulder pain.
Dantas & Lima, 2015	Dentists (n=387)	NMQ, together with questions about physical workload	Prevalence, Chi-squared test	The body part most affected by MSD is lower back (58.4%), the least affected body part is elbow (10.3%), tables of relationship between body parts and physical workload

Table 3.1 continues

Dianat et al., 2015	Sewing machine operators (n=251)	NMQ, Together with a systematic observation-based method (i.e. RULA)	Univariate logistic regression analyses, Prevalence, Multiple Logistic Regression Analyses, Descriptive analysis	79.6% of the employees suffer from MSD symptoms, Low back (58.9%), neck (54.1%), hands/wrists (40.2%), upper back (37.8%), shoulders (27.8%)
Azma et al., 2015	Nurses (n=144)	CMDQ, with a psychosocial risk assessment questionnaire	Prevalence, Pearson test	Regions with the most musculoskeletal discomforts: shoulder, back, neck, knee. Stress factors have been found to be enhancing musculoskeletal disorders.
Habibi et al., 2015	Nurses (n=247)	CMDQ, Together with a psychosocial and physical risk assessment questionnaire	Pearson correlation coefficient test, Spearman correlation coefficient tests, Prevalence	Risk regions most affected by musculoskeletal discomforts: leg (11.8%), knee pain (16.4%), neck pain (27.5%), shoulder pain (46.6%), low back pain (59%). Musculoskeletal disorders are associated with mental workload.
Ardahan & Simsek, 2016	Office workers (n=395)	CMDQ	Chi-square test, Logistic regression analysis, Mann-Whitney U test, Prevalence	Risk regions most affected by musculoskeletal discomforts: left shoulder (43.54%), right shoulder (45.32%), lower back (59.49%), back (66.33%), neck (67.85%). Work interference: left shoulder (31.9%), right shoulder (31.3%), lower back (30.6%), back (28.5%), neck (33.6%).
Simonsen et al., 2017	Female sonographer (n=291)	NMQ, Together with 2 psychosocial and 2 physical risk assessment questionnaires	Prevalence, Mc Nemar's test, Poisson Regression	2/3 of the sonographers experienced pain at least in one studied body parts. Table of personal factors and pain relations, Table of work-related actors and pain relations
Algarni et al., 2017	Medical Students at University Hospitals (n=469)	NMQ	Prevalence, Multivariable regression analysis, Chi-square test, Student's t-test, Mann-Whitney test	The percentage of MSD at least one body site at any time: 85.3%, in the past week: 54.4%, in the past year :81.9%. Factors associated with MSD: depressive, psychosomatic symptoms, history of traum.

14 articles used self-reported subjective judgement methods except the CMDQ, 8 articles used CMDQ. 42% of these studies also examined psychosocial risks because of its effect on musculoskeletal system discomfort. In these studies, subjective assessment methods were used together with a psychosocial risk assessment method. In some studies, subjective judgement methods have been used in conjunction with observational based methods. In 50% of the studies subjective judgement methods were used with another ergonomic risk assessment method.

3.2 Systematic Observation Methods

Observational techniques have been developed to record workplace risk exposures systematically and to conduct quantitative assessments (David, 2005). Observational methods are the most commonly used method by practitioners. These methods are often developed for practitioners within the context of occupational health and safety management and adapted to the needs of the workplace. These methods are easy to use, cost effective and flexible. (David, 2005)

Takala et al. (2010)'s study should be investigated for having extensive and detailed information about the systematic observational methods. Takala et al., 2010 conducted a systematic and detailed investigation of observational methods. The purpose of this review is to describe published observational methods that assess biomechanical exposures in the professional setting and to evaluate them according to the needs of different users. In their study, scientific databases and the internet for evaluation methods from 1965 to September 2008 is investigated. 30 appropriate observational methods are identified. 19 methods ranging from observer evaluation to video recordings are compared with other evaluation methods. Many of the observational tools evaluated in this study are not evaluated superior to each other. (Takala et al., 2010)

Systematic observations are divided into simple observational methods and advanced observational methods (David, 2005).

a. Simple Observation Based Methods

There are different techniques for evaluating the different parts of the body. Although some techniques only assess the posture of various parts of the body, the majority assess various critical physical exposure factors. (David, 2005)

David (2005) presented in his study that the simple observational evaluation tools listed in a table and examined them in terms of main features and functions. Information about these methods is given in Table 3.2. The methods in the table are as follows: Ovako Working Posture Analyzing System (OWAS) (Karhu et al., 1977), Rapid Upper Limb Assessment (RULA) (McAtamney & Corlett, 1993), National Institute of Occupational Safety and Health (NIOSH) Lifting Equation (Waters et al., 1993), Plan för Identifiering av belastningsfaktorer (PLIBEL) (Kemmlert, 1995), Strain Index (SI) (Moore & Garg, 1995), Occupational Repetitive Actions Index (OCRA) (Occhipinti, 1998), Quick Exposure Check (QEC) (Li & Buckle, 1999), Rapid Entire Body Assessment (REBA) (Hignett & McAtamney, 2000), American Conference of Governmental Industrial Hygienists Threshold Limit Values (ACGIH TLVs) (American Conference of Governmental Industrial Hygienists, 1995), Postural Loading on the Upper Body Assessment (LUBA) (Kee & Karwowski, 2001), Manual handling Assessment Charts (MAC) (Monnington et al., 2003).

Table 3.2 Simple Observation Based Methods (David, 2005)

Technique	Main features	Function
OWAS	Time sampling for body postures and force	Whole body posture recording and analysis
RULA	Categorization of body postures and force, with action levels for assessment	Upper body and limb assessment
NIOSH Lifting Equation	Measurement of posture related to biomechanical load for manual handling	Identification of risk factors and assessment
PLIBEL	Checklist with questions for different body regions	Identification of risk factors
SI	Combined index of six exposure factors for work tasks	Assessment of risk for distal upper extremity disorders
OCRA	Measures for body posture and force for repetitive tasks	Integrated assessment scores for various types of jobs
QEC	Exposure levels for main body regions with worker responses, and scores to guide intervention	Assessment of exposure of upper body and limb for static and dynamic tasks
REBA	Categorization of body postures and force, with action levels for assessment	Entire body assessment for dynamic tasks
ACGIH TLVs	Threshold limit values for hand activity and lifting work	Exposure assessment manual work
LUBA	Classification based on joint angular deviation from neutral and perceived discomfort	Assessment of postural loading on the upper body and limbs
MAC	Flow charts to assess main risk factors to guide prioritization and intervention	Assessment of risk factors for individual and team manual handling tasks

In addition to these methods, the following methods are also available in the literature (Takala et al., 2010): Health and Safety Executive (HSE) Upper Limb Assessment Method (HSE, 1990), American Conference of Governmental Industrial Hygienists Hand Level Activity (ACGIH HAL) (American Conference of Governmental Industrial Hygienists, 2008), Manual Tasks Risk Assessment

(ManTRA) (Burgess-Limerick et al., 2000), Back-Exposure Sampling Tool (Back-EST) (Village et al., 2008). In this section, different Simple Observation Based Methods are examined. The main features and functions of these methods are summarized by David (2005) and Takala et al. (2010)

b. Advanced Observation Based Methods

There are many video-based observation methods developed to assess the variety of postures in dynamic activities. Data obtained from these methods are recorded on video tape or on a computer. Records are performed in real time in a working period and the posture variations of the employees are recorded. Thanks to these methods, many features of employee postures can be determined. For example; accelerations, changes in the angle of movement, velocities and distances of movement. (David, 2005)

Advanced observation-based methods may include the use of biomechanical models for posture analysis and the usage of anthropometric, postural and hand-load data (Chaffin et al., 1999). The costs of the systems that need to be set up to use these methods can be high, and a specialized technical team is required in the use of these systems. These methods are more appropriate to record and analyze simulated works than to practical use around the workplace because, it is necessary to devote much time to the use of these methods. (David, 2005)

In David (2005)'s study, a list of some advanced observational methods is presented. This list contains information about the name, reference, main features and function of the technique. David (2005)'s list is given in Table 3.3. The methods in the table are as follows: Video analysis (Armstrong, 1986), ROTA (Ridd et al., 1989), Task Recording and Analysis on Computer (TRAC) (van der Beek et al., 1992), Hands Relative to the Body (HARBO) (Wiktorin et al., 1995), Portable Ergonomic Observation (PEO) (Frasson-Hall et al., 1995), Video analysis (Yen & Radwin, 1995), Posture, Activity, Tools and Handling (PATH) (Buchholtz et al., 1996), SIMI (Li & Buckle, 1999), Biomechanical models (Chaffin et al., 1999), Video analysis (Fallentin et al., 2001), Video analysis (Spielholtz et al., 2001) and Video analysis (Neuman et al., 2001).

Table 3.3 Advanced observational methods samples (David, 2005)

Technique	Main features	Function
Video analysis	Time sampling of video films and computerized data acquisition for both posture and force	Posture assessment of hand/finger
ROTA	Computerized real time or time sampling recording and analysis of activity and posture	Assessment of dynamic and static tasks
TRAC	Computerized time sampling recording and analysis of activity and posture	Assessment of dynamic and static tasks
HARBO	Computerized real time recording of activity and posture	Long duration observation of various types of jobs
PEO	Computerized real time recording of posture and activity	Various tasks performed during period of job
Video analysis	Analogue data recordings synchronized with video images	Various manual tasks
PATH	Computerized work sampling of posture and activity	Non-repetitive work
SIMI	Motion Video-based analysis of three dimensional movement	Assessment of dynamic movement of upper body and limbs
Biomechanical models	Linked segmental representation of the human body	Estimation of internal exposures during task performance
Video analysis	Tri-axial video-based observational method for quantification of exposure	Computerized estimation of repetitiveness, body postures, force and velocity
Video analysis	Video-based recording of upper extremity posture	Assessment of dynamic and static tasks
Video analysis	Digital video capture and analysis of body postures	Measurement of trunk angles and angular velocities

This table provides information about 12 advanced observation-based methods. The main features of these methods are listed in the table. The functions of these methods are also summarized. In addition to these methods, the following methods are also available in the literature: AnyBody Modeling System and Three-Dimensional Static Strength Prediction Program (3DSSPP). 3DSSPP is usually available with AutoCAD software (Feyen et al., 1999). AnyBody Modeling System analyzes the musculoskeletal system. AnyBody enables only the inverse dynamic model analysis. There are other software that are commercial and interested in the model of the human body. These are Jack and eM-Human by UGS, Human Builder by Safework, and Ramsis by Human Solutions. In this study, video shots have been performed even though advanced observation-based methods have not been used directly. Video shots have been analyzed to help with Rapid Entire Body Assessment. (Damsgaard et al., 2006)

3.3 Direct Measurement Methods

There are many methods of measuring by attaching to the subject in order to determine the variables exposed in the work. There are a variety of direct measurement methods. These methods can be simple and hand-held devices, or electronic goniometers. Simple methods are used to measure the range of joint motion. Electronic goniometers are used for continuous recording of joint movements during work. There are advantages and disadvantages of these direct measurement methods. These methods can provide accurate and reliable data. The sensors are directly connected to the subject and may cause some changes and discomfort. It is necessary to devote much time for analysis of these systems. Important initial investment is required for system installation and there is a need for qualified personnel. (David, 2005)

In David (2005)'s study, a list of some direct measurement methods is presented. This list contains information about the name, reference, main features and function of the technique. David (2005)'s list is given in Table 3.4. The methods in the table are as follows: The lumbar motion monitor (LMM) (Marras et al., 1992), Electronic goniometry (Radwin & Lin, 1993; Biometrics Ltd, 1998), Inclinometers (Hasson et al., 2001; Bernmark & Wiktorin, 2002), Body posture scanning systems (Li & Buckle,

1999), Electromyography (EMG) (Wells et al., 1997), Force measurement (Johnson et al., 2000) and CyberGlove (Frievalds et al., 2000).

Table 3.4 Direct measurement methods samples (David, 2005)

Technique	Main features	Function
LMM	Triaxial electronic goniometer	Assessment of back posture and motion
Electronic goniometry	Single or dual plane electronic goniometers and torsimeters to record joint posture	Measurement of angular displacement of upper extremity postures
Inclinometers	Tri-axial accelerometers that record movement in two degrees of freedom with reference to the line of gravity	Measurement of postures and movement of the head, back and upper limbs
Body posture scanning systems	Optical, sonic or electromagnetic registration of markers on body segments	Measurements of displacements, velocities and accelerations of a body segment
EMG	Recording of myoelectrical activity from exercising muscles	Estimation of variation in muscle tension and force application
Force measurement	Computer mouse with sensors recording forces applied to side and button	Determination of finger force exposures
CyberGlove	Lightweight glove incorporating 22 motion sensors and Uniforce pressure sensors	Measurement of wrist, hand and finger motion with superimposed grip pressure

This section provides information about 7 direct measurement methods. The main features of these methods are listed in the table. The functions of these methods are also summarized.

3.4 Psychosocial Evaluation Methods

Psychosocial risk factors are factors that affect the psychological reactions that an employee makes against work and workplace situations and potentially cause psychological health problems (Samra et al., 2009).

In 1981 Bertil Gardell defined five basic requirements for a psychosocial working environment. These five requirements are:

- The work should be organized so that the employee can influence his own working method and pace.
- The work should ensure that the employee perceives the entire product as a whole.
- The work should be organized so that the employee can fulfill his/her responsibilities and roles outside the work (family, social and political).
- The working order should allow individuals to use and develop their skills and resources.
- The working order should be open to human relations and cooperative possibilities at work.

There are many different scales to measure psychosocial risks. The main psychosocial risk scales are sorted as follows (Tabanelli et al., 2008):

- Copenhagen Psychosocial Questionnaire (Kristensen et al., 2005)
- Effort-Reward Imbalance (Siegrist et al., 2004)
- General Nordic Questionnaire (Lindstrom, 2002)
- Health and Safety Executive (HSE) Indicator Tool (HSE, 2004)
- Job Characteristics Index (Sims et al., 1976))
- Job Content Questionnaire (Karasek et al., 1998)
- Job Diagnostic Survey (Hackman & Oldham, 1975)
- Job Stress Survey (Vagg & Spielberg, 1999)
- Multidimensional Organizational Health Questionnaire (Avallone & Pamplomatas, 2005)
- Niosh Generic Job Stress Questionnaire (Hurrell & McLaney, 1988)

- Nova Web Questionnaire (Huys & De Rick, 2005)
- Occupational Stress Index (Belkic, 2000)
- Occupational Stress Indicator (Cooper et al., 1988)
- Occupational Stress Inventory (Osipow, 1992)
- Occupational Stress Questionnaire (Elo et al., 1998)
- Pressure Management Indicator (Williams & Cooper, 1998)
- Psychosocial Working Conditions (Widerszal-Bazyl & Cieslak, 2000)
- Stress Diagnostic Survey (Ivancevich et al., 1983)
- Stress Regulation Scale (Stress D'organisation Questionnaire) (PREVENT, 2005)
- Stress Profile (Setterlind & Larson, 1995)
- Stress Risk Assessment Questionnaire (SRA, 2003)
- Work and Health (Travail Et Santé) (CNT, 2004; FGTB, 2002)
- Tripod Sigma Questionnaire (Wiezer & Nelemans, 2005)
- Question and Work Experience Evaluation (Vragenlijst Beleving En Beoordeling Van De Arbeid) (Van Veldhoven & Broersen, 2003)
- Work Environment Scale (Moos, 1981)
- Working Conditions and Control Questionnaire (De Keyser & Hansez, 1996)
- WHOQOL-BREF Questionnaire (Nelson & Lofty, 1999)

In Table 3.5, 8 studies have been examined. The following tables contain the following information about the articles: participants, number studied (n), using methods, applied analyzes and study findings. The studies that have been performed in the last 24 years.

Table 3.5 Literature review for psychosocial risk

Article	Study Sample	Methods	Analyzes	Findings
Bernard et al., 1994	Newspaper employees (n=1050)	Niosh Generic Job Stress Questionnaire, together with a self-administered questionnaire	Logistic regression, factor analysis, Cronbach alpha coefficient, Student's t-test, an analysis of variance, chi-square test	There is a relationship between the psychosocial risk factors in the workplace and the occurrence of occupational musculoskeletal system diseases.
Houtman et al., 1994	The working population (n=5865)	A psychosocial risk assessment questionnaire	Multiple logistic regression analysis, factor analysis	The following factors were found to be influential in the formation of both psychosomatic and musculoskeletal disorders: low intellectual discretion, physical stressors and working at high pace.
Hogh & Dofradottir, 2001	Employees (n=4000)	Stress Profile Questionnaire	Factor analysis, logistic regression analysis	Exposure to negative actions, rather than the amount of negative actions, is the cause of the change in behavior as a further fact.
Devereux et al., 2002	Manuel handlers (n=1514)	A self-administered questionnaire	Prevalence, multiple logistic regression, Pearson's χ^2 test	It was found that an association between physical and psychosocial risk factors and these factors increase the risk of reporting symptoms of the upper limbs in the workplace.

Table 3.5 continues

Kristensen et al., 2004	Adult working Danes (n=1858)	Copenhagen Psychosocial Questionnaire	Logistic and linear regression analyses, factor analyses, analyses of internal reliability (Cronbach's alpha)	The scales on quantitative requirements were said to be very sensitive to the selection of particular items.
Hogh & Mikkelsen, 2005	Employees (n=4000)	A psychosocial risk assessment questionnaire	Pearson's correlation, Spearman's rho, linear regression analysis	Employees exposed to violence are lower sense of coherence than those who are not exposed.
Nübling et al., 2006	Employees (n=2561)	Copenhagen Psychosocial Questionnaire	Descriptive statistics, parametric and non-parametric correlation analyses, explorative-confirmatory factor analyses, simple and multiple regression analyses, reliability analyses	The reliability and validity of the German Copenhagen Psychosocial Questionnaire were proven.
Chakraborty et al., 2018	Construction workers (n=268)	Occupational Stress Index, NMQ, WHOQOL-BREF Questionnaire	Linear regression, Cronbach alpha coefficient, one-way ANOVA, prevalence	Workers have a musculoskeletal pain in the parts of the body that are often used in jobs and they are stressed out because of long working hours.

In 25% of the studies examined, psychosocial risks are evaluated together with physical risks. The relationships between these two types of risk are investigated. In this study, Copenhagen Psychosocial Questionnaire Method has been used to evaluate psychosocial risks. Detailed information about this method and its application is explained in Chapter 6.

CHAPTER FOUR

MULTI CRITERIA ANALYSIS

In a work place, there exists various ergonomic risk factors at the same time. However, it is not usually possible to evaluate all of these risk factors by using a sole assessment method. Therefore, different assessment methods, which generate different results with different assessment scales are to be used within in a work place. In order that there will be effective ergonomic risk assessment structure, it is important that there should be some common ground, i.e. a degree of unified evaluation, interpretation and understanding among the methods. In this thesis, multi-criteria analysis is used to form this common ground. The following sections contain information about multi criteria decision making, multi criteria decision making methods and literature review on studies using multi-criteria analysis in ergonomic risk assessment.

4.1 Multi Criteria Decision Making

Decisions that have no long-term effect on real life and decisions affecting only the person making the decision are very few. Very few decisions in business are simple decisions. Therefore, the impact of these decisions is quite wide. Decisions made by the business affect all stakeholders. There are alternatives and criteria for each decision. The main challenge of this process is to act in consideration of the interests of all stakeholders in the decision-making phase. At this stage, the most crucial question is “How can we choose the right choice considering the needs and wishes of all groups?”. So, a methodology that can measure each option according to a set of criteria and allowing each option to be compared in a simple way is needed. The most commonly used methodology is Multi Criteria Decision Making (MCDM). (Horder 2009)

MCDM is divided into two classes as MODM (multi-objective decision making) and MADM (multi-attribute decision making) according to Zimmermann (1996). MADM is used in this study. However, in MODM problems that have continuous decision space are studied. Mathematical programming problems can be example. In

MADM, problems with discrete decision space are studied (Triantaphyllou, 2000). The concepts used in decision problems are described below.

Alternatives:

Alternatives are different action options offered to decision makers (Triantaphyllou, 2000).

Attributes:

Attributes are called “goals” or “decision criteria”. If the number of criteria is too high a hierarchical structure can be created (i.e. there are sub-criteria below the main criteria) (Triantaphyllou, 2000).

Conflict among criteria:

It expresses the contradiction of multiple criteria (Xu & Yang, 2001). For example, there may be a contradiction between cost and profit (Triantaphyllou, 2000).

Incommensurable units:

Incommensurable units express that different criteria can have different units of measurement (Triantaphyllou, 2000).

Decision weights:

In most MCDM methods the importance weights of the criteria should be determined (Triantaphyllou, 2000).

Decision matrix:

Decision matrix is used to express decision problems. For example, a decision matrix A is a $m \times n$ matrix and the element of this matrix is a_{ij} (for $i = 1, 2, 3, \dots, m$, and $j = 1, 2, 3, \dots, n$). Example of a decision matrix is given in Figure 4.1. An element shows that when A_i alternative is evaluated by the C_j criterion In Figure 4.1 (Triantaphyllou, 2000).

Alts.	Criteria				
	C_1 (w_1)	C_2 w_2	C_3 w_3	...	C_n w_n)
A_1	a_{11}	a_{12}	a_{13}	...	a_{1n}
A_2	a_{21}	a_{22}	a_{23}	...	a_{2n}
...	...	...	...	...	...
A_m	a_{m1}	a_{m2}	a_{m3}	...	a_{mn}

Figure 4.1 Typical Decision Matrix (Triantaphyllou, 2000)

MCDM consists of six steps according to Opricovic & Tzeng (2004). Application steps of MCDM are as follows:

- i. Determination of evaluation criteria related to the goals
- ii. Creation alternatives to achieve goals
- iii. Assessment of alternatives with regard to criteria
- iv. Implementation of MCDM method
- v. Admission one of the available alternatives as the optimal choice
- vi. If an unacceptable result is obtained, the new data should be collected and the next iteration should be made.

Steps (i) and (v) are carried out by senior decision-makers, while other steps are engineering tasks. At step (iv) decision makers should set priorities according to the relative importance of the criteria. Creation and assessment of the alternatives (steps ii and iii) are activities at engineering level. (Opricovic & Tzeng, 2004)

4.2 MCDM Methods

MCDM is often used for decision making with multiple conflicting criteria. MCDM problems are frequently encountered in our personal and business contexts in our daily lives. Of course, the MCDM problems in the business context are rather complex and large-sized according to the personal context. Although the MCDM problems are always widely seen, its history is as short as 30 years. Development of computer technology has contributed to the advancement of MCDM discipline. The solution of

complex MCDM problems has been made possible by advancing computer technology. (Xu & Yang, 2001)

There are numerous MCDM techniques and approaches based on different theoretical grounds, asking different questions and obtaining different types of results. Many of the recommended methods for a particular problem may not be applied in another problem. therefore, when selecting the appropriate MCDM method, some criteria and key should be noted. (Mardani et al., 2015) MCDM methods which are frequently encountered in literature are given in the Table 4.1. Except the names of the methods in the table, short information about the methods are also included.

Table 4.1 MCDM Methods

Method	Description
Analytical Hierarchy Process (AHP) (Saaty, 1980)	AHP is a powerful and easy-to-understand method that allows groups and individuals to combine qualitative and quantitative factors in decision-making (Saaty, 1990).
Analytic Network Process (ANP) (Saaty, 1999)	The basic concept of ANP is to permit interaction and feedback within clusters and between clusters (Saaty, 2013).
Technique for Order Preference by Similarity to Identical Solution (TOPSIS) (Hwang & Yoon, 1981)	That the chosen alternative should be the shortest distance from the ideal solution and the shortest distance from the negative ideal solution is the basic logic of this method (Triantaphyllou, 2000).
Elimination and Choice Translating Reality (ELECTRE) (Benayoun et al., 1966)	In this method, "outranking relations" is applied by using the comparisons between the alternatives under each of the criteria (Triantaphyllou, 2000).
Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) (Brans & Vincke, 1985)	The relative importance of the criteria and the preference functions of the decision maker are important in this method (Macharis et al., 2004).
Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) (Opricovic, 1998)	The focus of this method is to sort and select from an alternative set. The compromise solution is obtained for problems with contradicting criteria (Sayadi et al., 2009).

In this study, one of the MCDM methods, ANP method is used. Information on the selection phase of this method is given in Chapter 6. Section 6.4.3 contains detailed information about the application stages of this method.

4.3 Literature Review on Studies Using Multi-Criteria Analysis in Ergonomic Risk Assessment

The MCDM discipline is used for different purposes in many different sectors. As the MCDM will be used in the ergonomic risk assessment in this study, the studies using multi criteria decision analysis methods for ergonomic risk assessment are examined in the literature. Some studies in the last eight years related to this subject are mentioned below.

In Görener (2011)'s study, the selection process of enterprise resource planning software is considered. Multiple quantitative and qualitative criteria are considered in this selection process. The necessity of the software being ergonomic is also one of the determined sub-criteria. The aim of the study is to select the best of the four software options using the integrated ANP-VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje) method.

Aminbakhsh et al. (2013)'s study includes safety risk assessment. Ergonomics plays an important role in all occupational sectors. Employees in each sector are exposed to health and safety risks. One of the sectors where such risks have serious consequences is the construction sector. So, it is very important to plan, manage and budget risks related to occupational health and safety. In this study, a model proposal is presented using the theory of cost of safety model and analytical hierarchy method, which is one of the multi-criteria decision methods. This proposed model allows the decision makers in the construction sector to determine the injury and accident prevention investments according to the budget.

Rossi et al. (2013)'s study aims to select the most effective of the material handling alternatives. They use multi criteria decision making approach to achieve this goal. In this study, the method chosen for the decision-making phase is the analytical hierarchy process method. Another aim of the study is to apply the multi-criteria decision-making approach proposed for manual handling to a real-life problem. The strategic

criteria in the study are "ergonomic and safety performance" and "production performance". This study presents choice of the best material handling method and real-life application by evaluating these two criteria.

Ahmadi et al. (2017)'s study has been carried out in the packaging and assembly industry. This study offers an approach to prioritize the measures of the ergonomic checkpoints of International Labour Organization. For this purpose, Analytical Network Process (ANP) and Fuzzy Decision Making Trial and Evaluation Laboratory methods have been used. An experimental study has been carried out in a packaging and assembly industry.

Alkan & Ilgin (2018)'s study proposes a three-step approach that enables ergonomic assessment of assembly lines in an electronics company. The first stage involves ergonomic analysis of assembly lines using three different methods (the risk assessment questionnaire, the National Institute for Occupational Safety and Health method, and the ergonomic control manual used by the company). The second stage involves identification of prioritization required lines and stations with Analytical Hierarchy Process method and Technique for Order Preference by Similarity to Ideal Solutions method. The third stage involves the calculation of non-value added time in the lines by applying time study. Correlation analysis has been conducted and it has been found that insufficient ergonomic conditions are effective in increasing the added value times.

In this section, some studies using the multi-criteria decision-making method related to ergonomics are given. Studies in different sectors have been examined. Multi-criteria decision-making methods related to ergonomics are used for different purposes in many different sectors. In these studies, ergonomics factor is commonly considered as a criterion. In some studies, multi-criteria decision-making methods are used as a tool to make workplaces suitable for occupational health and safety. Making workplaces suitable for ergonomics is an important issue. There are almost no studies using multi-criteria decision-making methods to evaluate ergonomic risk assessment methods together. These risk factors need to be considered in an integrated way, as there are more than one ergonomic risk factor affecting an employee at a workplace and there is no integrated methodology that evaluates these different ergonomic risk

factors. The aim of this study is to establish an integrated ergonomic risk assessment methodology with the usage of multi-criteria decision making methods. Multi-criteria decision-making methods play an important role in this study at this point.



CHAPTER FIVE

THE PROPOSED METHODOLOGY

This chapter describes the proposed methodology in this study. An integrated ergonomic risk assessment methodology not previously proposed is described in this chapter. Risk assessment is important for prevention of occupational musculoskeletal system disorders (OMSD) and occupational accidents (EU-OSHA, 2018). The use of existing risk assessment methods in the literature alone are not sufficient to identify work's risk level. Determining the risk level of a work using the methods assessing the one type risk does not give accurate and reliable results. In order to determine the risk level of a work, firstly all risks affecting that work should be determined. It is very important to establish a common evaluation according to the identified risks and to determine the risk level of the work in terms of the reliability of the evaluation. As well as subjective methods, observational methods and records from the workplace health unit should be included in the assessment of the objectivity of the assessment.

All risks in the system need to be taken into account to ensure accurate and reliable risk assessment. It is not sufficient to detect the present occupational musculoskeletal disorders in employees by examining infirmary records. However, there are employees who have work-related musculoskeletal disorders and who do not apply to the infirmary. So, examining only the infirmary records is not sufficient and accurate in terms of detecting work-related musculoskeletal disorders. It is necessary to collect information from the employees through the self-reported subjective judgement method in order to obtain general and accurate information about the complaints of occupational musculoskeletal system disorders and the collected information needs to be examined. So, a subjective risk assessment tool should be used. (Felekoğlu & Taşan, 2017) An integrated assessment of both observational and subjective methods should be made to achieve accurate and reliable results in a risk assessment. The difference the methodology proposed in this study is that it evaluates all types of risk affecting work on a common ground and both observational and subjective methods can be evaluated on a common ground. Thus, the level of risk of any work is assessed accurately.

The proposed methodology in the study consists of seven phases. These seven phases are as follows: Literature review specifically for the intended sector, System analysis, Preliminary risk analysis for potential risk factors in work environment, Proposing the structure for integrated ergonomic risk assessment with multi-criteria analysis (IERAMCA), Application of methods in IERAMCA methodology separately, Integrated ergonomic risk assessment using IERAMCA, Recommendations of possible intervention. These phases are shown in Figure 5.1. The seven phases should be applied in the sequence shown in the Figure 5.1. There are also steps of these phases. These steps of the phases are listed and described in detail after the Figure 5.1.

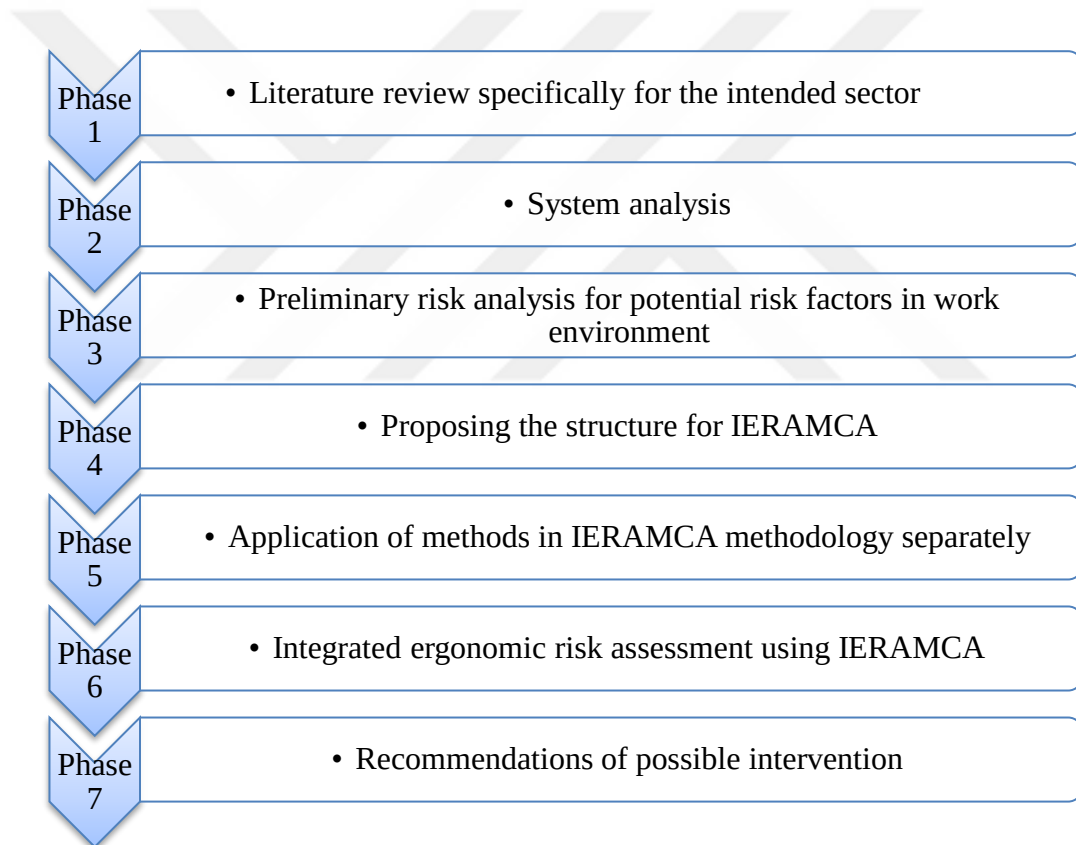


Figure 5.1 The proposed methodology

The proposed methodology in this study is as follows with the application phases and steps:

Phase 1: Literature review specifically for the intended sector

1.1 Literature review on the factors causing OMSD

1.2 Literature review on the evaluation methods of ergonomic risks affecting OMSD

Phase 2: System analysis

2.1 Determination of work steps

2.2 Construction of workflow

Phase 3: Preliminary risk analysis for potential risk factors in work environment

Phase 4: Proposing the structure for IERAMCA (A new methodology proposal is made considering risk factors in Phase 3.)

4.1 Selection of ergonomic risk assessment methods to cover or assess potential risk factors alone or together

4.2 Formation of the integrated structure to evaluate the results of these methods

4.3 Selection of multi-criteria analysis method that is suitable for the structure in step 4.2

4.4 Adaptation integrated ergonomic risk assessment into multi-criteria analysis method

4.4.1 Formation of multi-criteria analysis model

4.4.2 Determination of weights

Phase 5: Application of methods in IERAMCA methodology separately

5.1 Data collection (observation, record...)

5.2 Method usage

5.3 Result evaluation

Phase 6: Integrated ergonomic risk assessment using IERAMCA

6.1 Creation a common scale for all risk assessment methods

6.2 Evaluation of results with common scale and interpretations

Phase 7: Recommendations of possible intervention

7.1 Recommendation of behavioral measures

7.2 Recommendation of engineering measures

7.3. Recommendation of organizational measures

According to the general ergonomic risk assessment methodology proposed in this study, in Phase 1, a literature review specifically for the intended sector should be conducted on risk factors that may affect the employees in the workplace environment. In Phase 2, ergonomic risk assessment methods used to evaluate these factors should be investigated and literature on this subject should be screened. Then the system (work) needs to be examined in detail. All core and sub work steps in the system must be determined by observations. A general workflow of the system should be established with the identification of work steps. Determination of the workflow provides convenience in the identification of risks in the system. In Phase 3, the potential risk factors for each work step identified in Phase 2 should be examined and a preliminary risk analysis study should be carried out. The number of employees affected by the potential risk factors and the degree of impact of these risk factors on work should be identified. So, the risk level of the work is determined.

There are many risk factors in the working environment and there are many different methods to evaluate these factors. The use of these methods alone is not accurate and reliable to determine the level of working environment risks. Therefore, several methods should be considered together in the assessment of working environment risks. In Phase 4, the structure of IERAMCA methodology is proposed. This new methodology should be applied by taking into account the risk factors in Phase 3. The steps of Phase 4 are as follows: selection of ergonomic risk assessment methods to cover or assess potential risk factors alone or together, formation of the

integrated structure to evaluate the results of these methods, selection of multi-criteria analysis method that is suitable for the structure in step 4.2 and adapting integrated ergonomic risk assessment into multi-criteria analysis method. When adapting the integrated ergonomic risk assessment to the multi-criteria analysis method, multi-criteria analysis model should be formed. Then weights should be determined. Integrated structure of IERAMCA methodology is depicted in Figure 5.2.

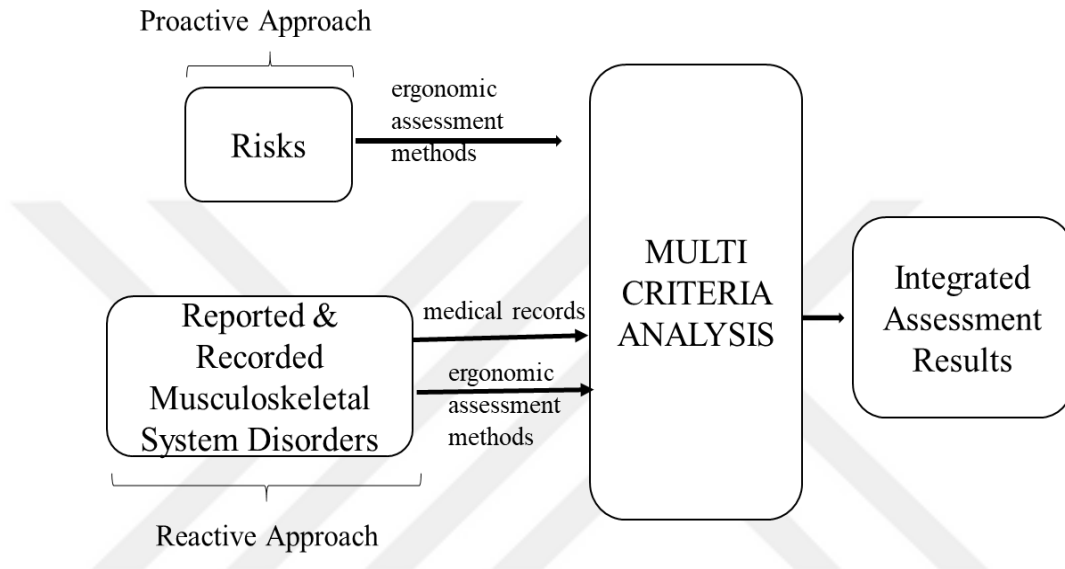


Figure 5.2 Integrated structure of IERAMCA methodology

In Figure 5.2, in the formation of the integrated structure to evaluate the results of the ergonomic risk assessment methods, proactive and reactive approaches are used together. Data from two branches is used when creating this integrated methodology. These are two branches: Risks and Reported & Recorded Musculoskeletal System Disorders. Data on risks in the system are obtained using ergonomic risk assessment methods. Data on reported & recorded musculoskeletal system disorders are obtained using medical records and ergonomic risk assessment methods. All data obtained are evaluated in a common structure with multi-criteria analysis. Then, a single integrated assessment result is obtained.

Phase 5 is the application phase of the methods in IERAMCA methodology separately. In this phase, the necessary data for the application must be collected by observations and records. Then selected methods are used and evaluation results are obtained. In Phase 6, integrated ergonomic risk assessment using IERAMCA should

be performed. Results obtained in step 4.4 should be used in this stage. In this phase, a common assessment scale should be established for all risk assessment methods applied. Secondly, assessment results should be evaluated with common scale and interpretations. In Phase 7, intervention (behavioral, engineering or organizational) proposals should be submitted and applied. Intervention results should be interpreted and sustainability of improvements ensured.

It can be clearly seen that the proposed new methodology will bring a new perspective to the field of ergonomic risk assessment. A method of assessing together all the elements taken into account in this methodology has not been suggested so far. Most ergonomic risk assessment method involves subjectivity. This methodology allows an objective ergonomic risk assessment.

Real life application of the proposed methodology will be made in this study. The real-life application of these 7 phases is in Chapter Six. The implementation of this methodology will be carried out in the laboratory of Dokuz Eylül University Hospital Blood Center. The application will be carried out in order of 7 phases according to the methodology. This proposed methodology offers a generic structure that can be used in different sectors in ergonomic risk assessment studies.

CHAPTER SIX

APPLICATION OF PROPOSED METHODOLOGY IN A UNIVERSITY HOSPITAL LABORATORY

This chapter includes the real-life application of the proposed methodology in this study. The proposed methodology in this study consists of seven phases. There are also steps of these seven phases. In this chapter, the application of these seven phases and the steps of these phases have been carried out respectively. The real-life application of the proposed methodology has been carried out in the laboratory of Dokuz Eylül University Hospital Blood Center. Ergonomic risk assessment has been performed in the blood center laboratory with the proposed methodology. The following sections are: Literature Review on the Health Care Sector, System analysis, Preliminary risk analysis for potential risk factors in work environment, Proposing the structure for integrated ergonomic risk assessment with multi-criteria analysis, Application of methods in integrated ergonomic risk assessment with multi-criteria analysis methodology separately, Integrated ergonomic risk assessment using integrated ergonomic risk assessment with multi-criteria analysis, Recommendations of possible intervention.

6.1 Phase 1: Literature Review on the Health Care Sector

Health care sector is one of the work areas that have significant risks for occupational health and safety. It is stated that hospitals are complex systems because they are based on a wide variety of profession groups which are most physically challenging. There are many risk factors that affect the health of employees in hospitals. (Janowitz et al., 2006) The likelihood of health care employees facing occupational risks varies according to occupation and department (Parlar, 2008). As the health care sector provides services directly to people, a small mistake during work can lead to irremediable problems (Karadağ & Yıldırım, 2004).

Due to the working environment of the health care sector, intermittent control examinations of health workers should be performed and the working environment should be assessed. Precautions should be taken to ensure that employees are not affected by the working environment risks and that the health of employees is

protected. Employees should be informed about risk factors. Risk factors and risk levels in the working environment should be determined. (Bilir, 2005)

The following information about the workplace risk factors exposed by health care workers and the literature survey on the methods used to assess these risks are given below.

6.1.1 Literature Review on the Factors Causing Occupational Musculoskeletal System Disorders in the Health Care Sector

One of the largest sectors in Europe is the health care sector and around 10% of employees in the European Union are working in the health care and welfare sector. A considerable number of these employees work in hospitals (E-FACT, 2007). Work environment risks that affect healthcare workers in terms of musculoskeletal disorders: technical factors, organizational factors, factors related to work task, individual factors and psychosocial factors. Technical factors contain slippery floor, poor ergonomic working environment designs (inadequate design for lounging movements, etc.), improper temperature, humidity, ventilation and lighting. Organizational factors contain lack of rest breaks, insufficient equipment support, shortage of regular equipment maintenance, lack of training support, insufficient number of employees, lack of protective equipment and inadequate design of workflow. Factors related to work task contain lifting and transportation of very heavy, large, hard to grasp and unbalanced materials, non-neutral postures, prolonged sitting or standing, repetitive movements. Individual factors contain shortage of experience and training, height, weight, age, chronic disease, lack of attention, responsibility and personal habits. Psychosocial factors contain high job expectations, insufficient instruction, not to limit employee responsibilities clearly, working pace and time pressure, relations with colleagues and lack of assistance.

Parlar (2008) pointed out the risk factors that may affect the health and safety of health care workers in the work environment: biological, chemical, physical, environmental, psycho-social and biomechanical risks. Pınar (2010) have conducted a research in order to determine work-related musculoskeletal disorders and related factors in Turkish nurses. Study sample is 2400 nurses working in various hospitals in

Istanbul. Data have been collected by questionnaire method. The highest prevalence is seen in waist, shoulder and neck respectively. The most common causes of musculoskeletal complaints are heavy lifting (92.3%), prolonged standing (89.8%) and bending. The results of this study show that the work-related factors that cause musculoskeletal disorders in nurses are universal (Pınar, 2010).

Long et al. (2012) have conducted a research on the risk factors affecting the musculoskeletal system disorders related to the upper limb in physicians, midwives and nurses. 87 studies have been examined and 18 studies have found to be appropriate. According to the results of the study, there is a strong relationship between occupational upper limb musculoskeletal disorders and job demands, hard work programs and physical risks (Long et al., 2012). Bernal et al. (2015) have conducted a study to investigate the relationship between workplace and occupational musculoskeletal system diseases and psychosocial risk factors in nurses. High psychosocial demands-low job control is associated with low back, shoulder and knee pain. There is a relationship between low social support and back pain. There is a relationship between the effort award imbalance and the prevalence of musculoskeletal disorders (Bernal et al. 2015).

6.1.2 Literature Review on the Evaluation Methods of Ergonomic Risks Affecting Occupational Musculoskeletal System Disorders in the Health Care Sector

This section includes the ergonomic risk assessment studies carried out in the health services sector. In the literature, there are many ergonomic risk assessment studies carried out in the health care sector for different occupational groups. Some studies use only subjective assessment methods, while others use only observational assessment methods. There are also many studies that apply ergonomic risk assessment using both subjective and observational assessment tools. Information on some studies in the literature are given below.

According to Hignett (1996), back pain is among the common occupational musculoskeletal system disorders in nursing. In Hignett (1996)'s study, it is aimed that measuring the severity of working positions (during manual handling processes) of nurses in the elderly care department. The OWAS (Ovako Working posture Analysis

System) method is used for this purpose in this study. For the analysis, 26 nurses are observed in 31 different positions and 4299 observations are obtained. The analysis shows that the percentage of harmful positions accepted pending patient handling process is higher than pending non-patient handling process. (Hignett, 1996)

Büker et al. (2006)'s study is a paper to examine the occupational musculoskeletal system disorders in physicians working at the hospital. A questionnaire consisting of 22 questions is applied to 123 physicians to determine the musculoskeletal disorders. 41 of the physicians participating in the study have been found to have musculoskeletal problems due to working conditions. According to the results of the study, it is a risk for the musculoskeletal system problems that physicians have to stay in the same position for a long time and have to repeat the same activities. (Büker et al., 2006)

The aim of Choobineh et al. (2006)'s study is to show the prevalence of musculoskeletal disorders in nurses. 641 nurses from 12 hospitals have participated in the study. The subjective ergonomic risk assessment methods used in the study are the Nordic musculoskeletal disorders questionnaire and Job Content Questionnaire. According to the results of the study, 84.4% of the nurses have experienced some symptoms of musculoskeletal disorders during the last 1 year. The most common discomfort among nurses is lower back discomfort. No relationship is found between the reported symptoms and psychological demands. (Choobineh et al., 2006)

Atasoy et al. (2010)'s study has been carried out a study to determine the ergonomic risks in a hospital laboratory in Turkey in order to uncover and work-related musculoskeletal problems in the employees. It is expressed in the study that in laboratory workers, repetitive physical movements, poor posture work, stress, repetitive and violent activities, long-term work without breaks, and poor ergonomic conditions cause occupational musculoskeletal disorders. The study has been conducted on 17 laboratory staff using questionnaires and observation forms. Nordic Musculoskeletal Questionnaire has been used for problems related to musculoskeletal system. In order to identify environmental and business management risk factors in the laboratories, the information on the evaluation forms in the guide to recognition and assessment of ergonomic risks prepared by the Canadian Petroleum Manufacturers Association has been used in this study. Also, in the study, REBA and workplace

layout observation forms have been used. According to the study results, pain prevalence is highest in the following body regions respectively: back, shoulder, lower back and neck. Ergonomic risk factors in the laboratory is determined as noise, chair condition, work stress, vibration, working pace and temperature. Laboratory staff are at moderate risk for work-related musculoskeletal disorders. (Atasoy et al., 2010)

The aim of Kim & Roh (2014)'s study is to analyze movements that may cause musculoskeletal disorders in radiological technologists. 7 radiological technologists have been observed for this purpose. Some work postures have been analyzed using four ergonomic evaluation methods. These methods are the Rapid Entire Body Assessment (REBA), the Rapid Upper Limb Assessment (RULA), the National Institute for Occupational Safety and Health Lifting Equation (NLE), and the Strain Index (SI). In radiological technologists, according to different working positions, the pain in neck, waist and leg is increasing. As a result, musculoskeletal disorders occur in different regions of the body in radiological technologists, but most commonly in the shoulder and waist region. (Kim & Roh, 2014)

6.2 Phase2: System Analysis

The real-life application of the proposed methodology was conducted in the blood center laboratory of Dokuz Eylul University Hospital. In this section, the laboratory where the application was carried out was analyzed. The general process structure analysis of the laboratory was carried out with the on-site observations and interviews with employees.

The blood center consists of the following 6 units according to data by the occupational health and safety unit of the hospital:

1. Donation room, Apheresis room
2. Laboratory, Stem Cell Chamber, Cooling Chamber
3. Irradiation Chamber
4. Corridor, Secretary, Examination Room
5. Offices, The Resting and Changing Rooms
6. Warehouse, Archive

In total 35 people are working at the Blood Center. 20 people from 35 people are laboratory workers. 18 people are laboratory technicians, a person is supervisor of the laboratory. A person is stem cell expert. According to the occupational health and safety unit of the hospital, blood center employees are at risk in terms of unhealthy working. Because the working environment includes occupational accidents and biological, ergonomic, chemical, physical and psychosocial risks.

Blood centers have to be open 24 hours. For this reason, there is a shift working system in the blood center laboratory. Day shift is eight hours, night shift is sixteen hours and weekend shifts are 24 hours. When considering one-month shift schedule, workload distribution among technicians is made so that, each technician works average 8 hours per day.

6.2.1 Determination of Work Steps

The works done in the blood center laboratory is divided into 3 processes. These processes include blood group identification process (P_1), product preparation process (P_2), and cross match process (P_3). The product preparation process is divided into two sub-processes: product separation (P_{21}) and serology (P_{22}). Figure 6.1 illustrates the hierarchical structure of laboratory process.

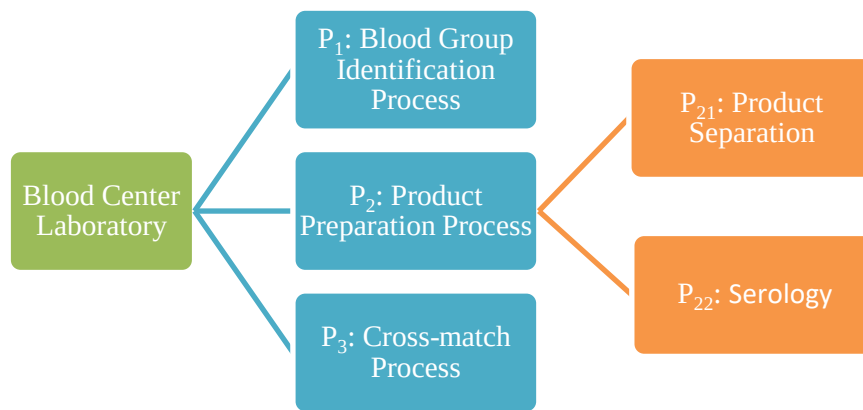


Figure 6.1 Hierarchical structure of processes in laboratory

In blood group identification process, the group to which the blood belongs is determined. The product separation sub-process consists of obtaining erythrocytes, plasma and platelets from whole blood. Serology sub-process consists of infectious disease screening tests. In the cross-match process, the match between the donated blood and the donor blood is investigated, it is compliance testing. These processes include 22 main tasks (see Table 6.1). However, the frequency of each main task in processes varies. According to the frequency information, tasks are divided into three groups; i.e. tasks done for each blood sample (*), tasks done for a group of blood sample (**), and non-routine tasks (***), they are not defined in process description, whereas are necessary for the functioning of the process. According to the Table 6.1, 45% of the main tasks are performed for each blood sample, 32% of the main tasks are performed for a specific group of blood sample, 23% of the main tasks are performed exceptionally.

Table 6.1 The list of main tasks

Main Task no (frequency)	Process Group	Main Task Definitions
1 (*)	P ₂₂	Taking Samples from Whole Blood Bag
2 (*)	P ₂₁	Centrifugation of Whole Blood Bags
3 (*)	P ₂₁	Erythrocyte and Plasma Separation
4 (**)	P ₂₁	Removal of Filtered Erythrocytes
5 (*)	P ₂₁	Platelet Separation
6 (*)	P ₂₁	Labeling of Products
7 (*)	P ₂₁	Plasma shocking process
8 (*)	P ₂₁	Thrombocyte pooling
9 (*)	P ₂₂	Infection Test
10 (*)	P ₂₂	Witness sample separation
11 (***)	P ₂₂	Loading distile water to the autoanalyzer
12 (***)	P ₂₂	Placement of the solutions required for the operation of the autoanalyzer
13 (**)		Tube Centrifuge in the Microcentrifuge
14 (**)	P ₃	Erythrocyte reservation
15 (*)	P ₁	Blood Group Identification Process
16 (***)	P ₁ -P ₃	Discharge of waste water from cross match and blood group machine
17 (***)	P ₁ -P ₃	Gel card centrifuge
18 (*)	P ₁ -P ₃	Manual filling of gel cards for blood group and cross match machine operations.
19 (***)	P ₁ -P ₃	Preparing cross and blood group machines for operating.
20 (**)	P ₃	Plasma and thrombocyte reservation
21 (**)	P ₃	Removal of reservations for products that expire at the end of the reservation.
22 (**)	P ₁	Blood irradiation technique

These 22 main tasks contain a total of 201 sub-tasks. The detailed information about these sub-tasks are given in Table 1 in the appendices section. All the laboratory technicians in the blood center are doing these processes alternately, where the work schedule is constructed by the laboratory supervisor as a monthly chart.

6.2.2 Construction of Workflow

In this section, the workflow in the laboratory is given. Some definitions related to the laboratory are also introduced. Some definitions of tasks done in the blood center laboratory are described below (Ayhan, n.d.):

- Blood products are products prepared for use in treatment.
- Whole blood is used directly from the donor without being taken to the bag and separated into its components.
- Erythrocyte suspension is blood that 75% of its plasma is taken.
- Leucocyte-reduced erythrocyte suspension (filtered erythrocyte) is blood that the plasma is removed and the leukocyte content is reduced. Today, the most suitable method is filter use.
- Frozen plasma is obtained by rapid freezing of fresh plasma in 6-8 hours.

The workflow of the product preparation process in the laboratory is illustrated in Figure 6.2. Whole blood bag comes with sample tubes to the laboratory. The tubes are separated from the blood bag and cross match sample is received from the hose of the bag. The bag is rested for 1.5 hours. Processes of the blood bag and the sample tubes are made simultaneously. The infection test sample is loaded into the autoanalyser after centrifugation. If the result is positive, tubes are left for labeling. If the result is negative, it is centrifuged again and loaded to the autoanalyser. Blood is destroyed if the result is negative again. The whole blood bag is centrifuged after resting. Erythrocyte and plasma separation procedures are performed. The remaining blood is rested for two hours it is centrifuged. Platelet separation is performed. Separated erythrocyte, plasma and platelet are labeled and stored. Blood group determination is performed simultaneously with the mentioned procedures above. Blood group information are also included in the product label. The cross-match samples are stored. In cross match process, blood compliance between the patient and the donor is tested. This process is done when blood demand is made for the patient. In Figure 6.2, the symbols A and B indicate the connection points in the workflow. The workflow continues from these connection points.

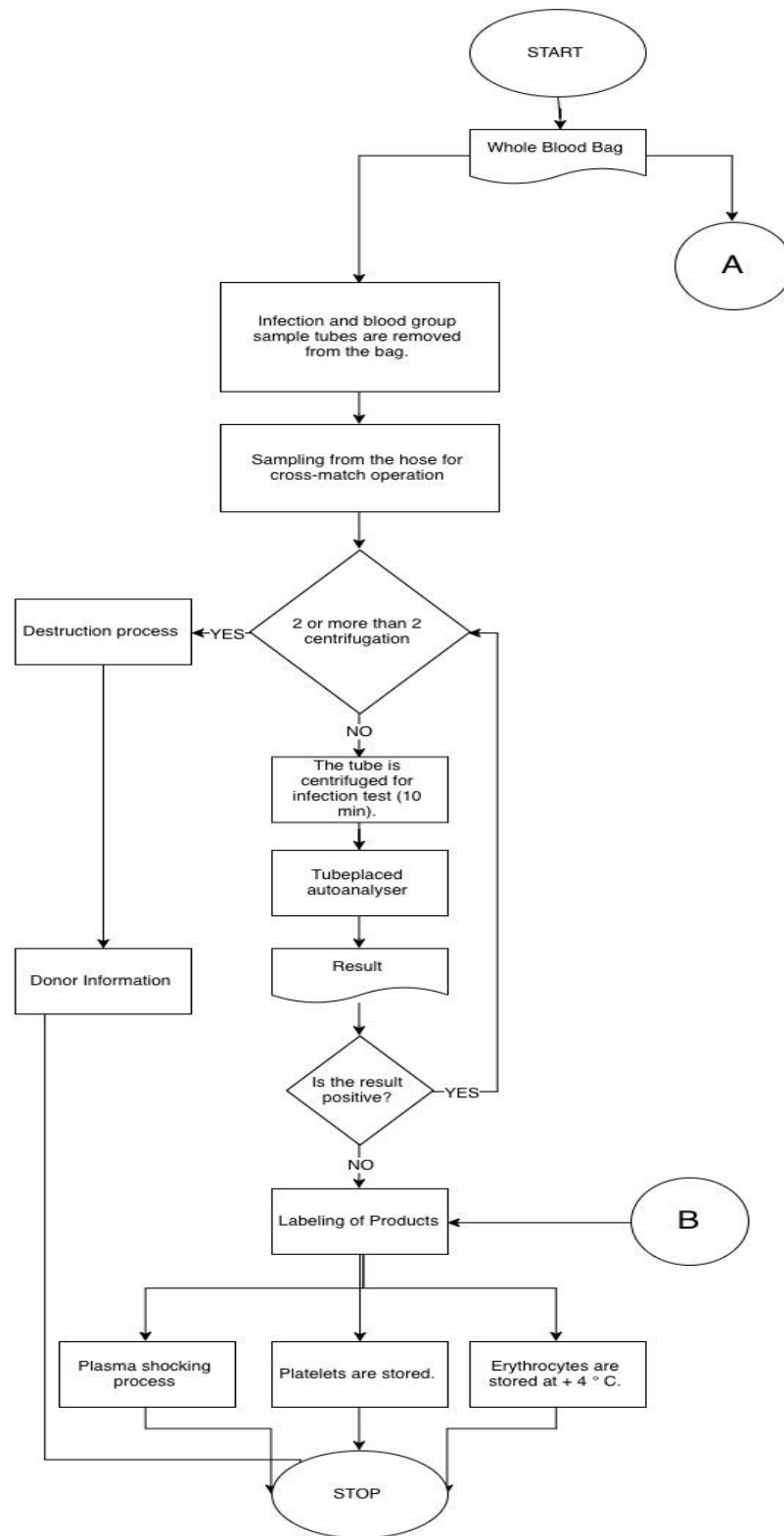


Figure 6.2 Work flow



Figure 6.2 continues

In this section, the tasks done in the blood center laboratory have been analyzed. Additionally, there are some definitions used in the laboratory. Laboratory workflow is described in this section.



6.3 Phase 3: Preliminary Risk Analysis Potential Risk Factors in Work Environment

Preliminary risk analysis potential risk factors in work environment have been carried out in this section. In this study, only the processes belonging to the laboratory have been examined in the blood center. There is an alternating working system in the laboratory. So, each laboratory technician is doing all the processes. Therefore, each laboratory technician is affected by the risks in the laboratory. The risks of each sub-tasks have been determined by the preliminary risk analysis study. Sub-tasks in the laboratory are affected by biological, chemical and ergonomic risks. The risks in the laboratory are categorized in Figure 6.3.

The most common biological risks in the laboratory are percutaneous injury and body fluid contamination. The most common chemical risks in the laboratory are latex, powder, detergents, disinfectants and solutions. Ergonomic risks are examined in three main groups: physical risks, environmental risks and psychosocial risks. The most common physical risks in the laboratory are working in a sitting position, working in a standing position, lifting heavy and bad posture. The most common environmental risks in the laboratory are noise, vibration and low heat. The most common psychosocial risks in the laboratory are working at high pace, hard-working, communication problems with employees and problems of participation in decisions.

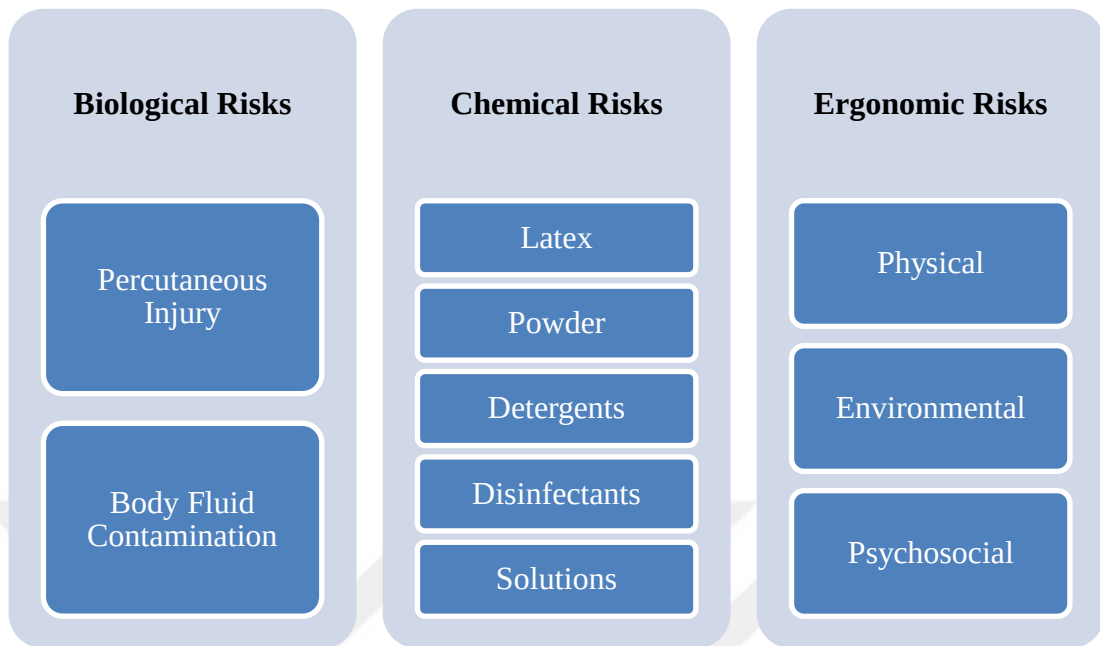


Figure 6.3 The risks in the laboratory

In the laboratory, physical, chemical and biological risks affecting the sub-tasks can be directly determined. But the environmental and psychosocial risks cannot be divided into sub-tasks. Because, the environmental and psychosocial risks are generally the risks that affect the laboratory working environment.

During the preliminary risk analysis of the laboratory, attention has been paid to the severity and impact of the risks. Therefore, the severity-impact matrix has been used to determine the level of risk of the sub-tasks in the laboratory. In Table 6.2, the severity-impact matrix is shown. The number of employees affected by risks and the business impact of risks have been examined through this matrix. Affecting of all laboratory staff is called as high severity, affecting an employee group is called as medium severity and affecting a laboratory staff is called as low severity. Stopping the laboratory processes is called as high impact, degrading of the laboratory processes is called as medium impact and presence of irritation is called as low impact. Risk level is determined by the severity-impact intersection in the matrix. Risk levels are emergency, critical, major, normal and low.

Table 6.2 Severity- impact matrix

	Number of Employees Affected			
		High Severity All laboratory staff are affected	Medium Severity An employee group is affected	Low Severity A laboratory staff is affected
	High Impact The laboratory processes are stopped	Emergency-1	Critical-2	Major-3
	Medium Impact The laboratory processes are degraded but, there is a reasonable work around	Critical-2	Major-3	Normal-4
	Low Impact There is an irritation but laboratory processes are not stopped	Major-3	Normal-4	Low-5

Each of the 201 sub-tasks has been examined according to severity-impact matrix. Table 2 is given in the appendices section All types of risk of the sub-tasks have been taken into account when creating Table 2. In Figure 6.4, percentages of risk levels are shown. According to the preliminary risk analysis, 28% of the sub-tasks is at emergency level, 15% of the sub-tasks is at major level and 57% of the sub-tasks is at critical level. There is no sub-task at level of normal and low. A large majority of the risks in laboratories is critical.

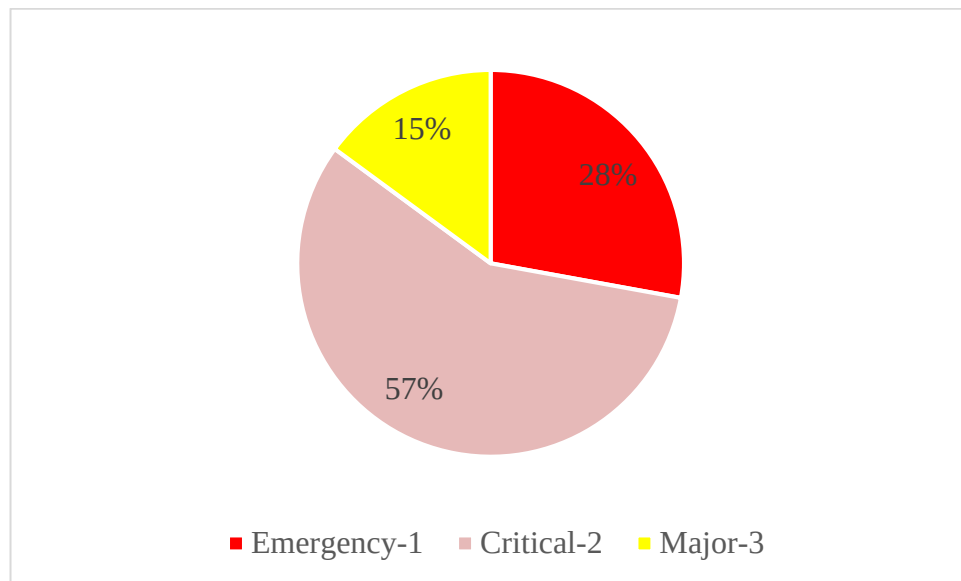


Figure 6.4 Percentages of risk levels

In this section, a preliminary risk analysis has been carried out in the laboratory environment. Firstly, risk factors in laboratory have been determined. Determined risk factors have been analyzed with severity-impact matrix. All sub-tasks have been examined in terms of risk factors. As a result of this analysis, the risk levels of all sub-tasks have been determined.

6.4 Phase 4: Proposing the structure for Integrated Ergonomic Risk Assessment with Multi-Criteria Analysis

In this section, the structure for integrated ergonomic risk assessment with multi-criteria analysis is proposed. The application steps in this section are as follows: selection of ergonomic risk assessment methods to cover or assess potential risk factors alone or together, formation of the integrated structure to evaluate the results of these methods, selection of multi-criteria analysis method that is suitable for the structure, adaptation integrated ergonomic risk assessment into multi-criteria analysis method.

6.4.1 Selection of Ergonomic Risk Assessment Methods to Cover or Assess Potential Risk Factors Alone or Together

This section describes the selection of ergonomic risk assessment methods to cover or assess potential risk factors alone or together. The reasons for the selection of these methods are also mentioned in this section. As mentioned previously, in this study, methods of evaluating physical and psychosocial risk factors affecting musculoskeletal disorders will be used. No other assessment will be made for other risk factors. However, there are brief explanations below about these risk factors.

The biological risks identified for all 6 units in the blood center are: percutaneous injury, body fluids contamination, respiratory-droplet-aerosol and working with pathogen. The possible biological risks in the laboratory are percutaneous injury and body fluids contamination. The chemical risks are: detergents, disinfectants, glutaraldehyde, formaldehyde, chemotherapeutics, drugs, latex, powder, iodine, acids, lead, anesthetic gases, mercury, flammable and explosive chemicals, tin, adhesive, welding gas, rust solvent, liquid nitrogen, device solutions. The possible risks of these chemical risks in the laboratory are detergents, disinfectants, latex, powder and device solutions.

The comfort and tiredness of the technician are affected by humidity, air currents, temperature, extreme noise, ambient lighting levels and ventilation. (Mitchell, 2010a) Identified environmental risks for the blood center are ionized radiation, electric-electromagnetic field, noise, vibration, dust, humidity, low temperature, high temperature. There is a risk of slipping and falling in the laboratory. Work materials and workplace floor should not allow to slip and fall (WHO, 2010). Electrical-electromagnetic field, screen reflection-glare, noise, vibration and low temperature factors are determined as blood center laboratory risks from these identified risks.

The physical risks identified for the blood center laboratory are: seating work, standing work, heavy lifting, improper posture work, repetitive motion, working with the screen. The accidents frequently seen in the blood center laboratory is determined as follows: falling, percutaneous injury, blood and body fluid contamination, musculoskeletal strain, chemical contamination, squeeze, physical violence, electric

shock, explosion. The findings of the working conditions in the laboratory are as follows: variable working time, shift working, night working, inadequate working area, inadequate resting area, inadequate changing rooms / lockers, inadequate WC-sink areas. The psychosocial risks identified for the blood center laboratory are: rapid work, intense work, physical violence, verbal violence, communication problems with patients or their relatives, communication problems with colleagues, participation problems with decisions.

The main purpose of this study is to evaluate both physical and psychosocial risks together in the ergonomic risk assessment. It is emphasized that it is important to use both subjective and observational methods. Subjective assessment methods alone and observer assessment methods alone are not sufficient to assess physical risks. The ergonomic risk assessment methods used in this study have been selected considering the risks detected in the laboratory. In this study, User Survey for Ergonomic Risks (Cornell University Ergonomics Web, 2014), Cornell Musculoskeletal Discomfort Questionnaire (Hedge et al., 1999), Rapid Entire Body Assessment (Hignett and Hignett & McAtamney, 2000) and Computer Workstation Checklist (Computer workstations etool, n.d.), methods have been chosen to evaluate physical risks. The Copenhagen Psychosocial Questionnaire (Kristensen et al., 2005) method has been chosen to evaluate psychosocial risks. The reasons for choosing these methods are explained below. These five methods are described with a specific sequence. This sequence has been determined by the type of risk that the methods evaluated and by observational or subjective methods. Firstly, methods that evaluate physical risks have been explained. Among the methods that assess physical risks, the subjective assessment methods are explained first. Because these methods are independent from the work and these methods depend on the employee statement. Then observational methods have been described. Finally, the method chosen for psychosocial risks has been described. This sequence is as follows: User Survey for Ergonomic Risks, Cornell Musculoskeletal Discomfort Questionnaire, Rapid Entire Body Assessment, Computer Workstation Checklist and Copenhagen Psychosocial Questionnaire methods.

One of the selected methods is User Survey for Ergonomic Risks, a method that assesses both environmental and physical risks. This method is a subjective assessment method. The most important factor in the selection of this survey is to evaluate physical and environmental risks together. This survey includes questions about physical risks. It also includes questions about environmental risks in the work environment. This method is understandable and very easy for the evaluators. Application of the method takes very little time.

The occupational health and safety unit of the hospital performed risk assessment throughout the blood center. According to the findings of this evaluation, musculoskeletal diseases were seen in 45.7% of blood center employees. Most of the employees who complain about the musculoskeletal system in the blood center are laboratory technicians. Therefore, in this study the Cornell Musculoskeletal Discomfort Questionnaire method was used to detect the existing musculoskeletal disorders of laboratory technicians and to reach the basic causes of occupational musculoskeletal system diseases of them. In this study the CMDQ method is used, a subjective assessment method.

One of the selected methods is the REBA method which is an observer evaluation method. The REBA method analyzes physical risks. This method has many advantages over other observer evaluation methods. Due to these advantages, REBA method has been used. To implement this method, you need a REBA form and a pen. The REBA method performs a holistic ergonomic risk analysis by evaluating a work posture and movement, forcing or loading, coupling and repetition. This method gives advice to the observer on the risk level of the work according to the score.

The Computer Workstation Checklist method has been chosen for the evaluation of computer-operated workstations. The VDT method is an observer evaluation method that evaluates physical risks. This method has many advantages. For the observer it is very easy to implement and is a clear checklist. In addition to questions about body postures, it also questions the ergonomic suitability of working materials. This method is of great importance in the evaluation of computer-operated workstations in the laboratory.

One of the important factors affecting musculoskeletal disorders is psychosocial risk factors. Employees are exposed to psychosocial risks due to some reasons because of the laboratory environment. In this study, the Copenhagen Psychosocial Questionnaire Method, which is the subjective assessment method for psychosocial risk factors, has been chosen because this method provides a comprehensive evaluation of psychosocial risks according to other methods. It evaluates 20 different psychosocial dimensions in detail. There are 69 questions in total. The evaluation is very easy and clear.

In this study, the following five methods for ergonomic risk assessment have been selected: User Survey for Ergonomic Risks, Cornell Musculoskeletal Discomfort Questionnaire, Rapid Entire Body Assessment, Computer Workstation Checklist and Copenhagen Psychosocial Questionnaire methods.

6.4.1.1 User Survey for Ergonomics Issues

The User Survey for Ergonomics Issues (USGBC) method contains questions about features that are required for a good ergonomic design in the workplace. (Cornell University Ergonomics Web, 2014). The USGBC form shown in Table 6.5. This survey not only question the ergonomic design of the workplace but also question the environmental risks to which employees are exposed at workplace. In Occupational Safety and Health Administration web site, some information is provided for environmental ergonomic conditions (Workstation environment, n.d.). Environmental risk factors should be determined so that the health of the employee does not fall into bad condition, and the job performance and motivation do not decrease. Environmental risk factors are factors such as noise, thermal comfort, lighting, ventilation. (Turan, 2016)

The noise in the working environment can have psychological effects on the individual according to severity. The most important effects of noise include: lack of concentration, lack of attention, nervousness, disagreements, tension and decreased perception. It is also very important to ensure that the, thermal comfort, humidity and ventilation in the work environment where the employees have spent a great deal of time. Because these factors directly affect employee health and work efficiency. One

of the other environmental factors in the working environment is enlightenment. Since lighting is a safe and convenient field of vision, it is an issue that businesses place emphasis on. (Turan, 2016)

This survey is asking for the features that are required for computer-based workplaces to have a good design. The features that an ergonomic computer workstation should have are listed below and these properties listed in this survey should be considered. This list includes features that should be related to the 12 regions of the ergonomic computer workstation. These 12 regions are shown in the Figure 5.2.

According to the order shown in Figure 6.6, these 12 regions must have the following characteristics (Cornell University Ergonomics Web, 2015):

1. Chair should be with adjustable chair back and seat back.
2. The highest level of the monitor 2-3 "(5-8 cm) should be above the eye level.
3. There should be no glare on the screen, if necessary an optical glare filter should be used.
4. The sitting distance monitor should be up to an arm length.
5. The feet should be on floor or supported by a stable foot support.
6. Preferably a document holder compatible with the computer screen should be used.
7. The wrists should be straight and the forearm and wrists should be in a straight line to use keyboard, input device and mouse.
8. Arms and elbows should be close and comfortable to the body.
9. The center of the monitor and the keyboard should be in front of the employee.
10. A negative sloping keyboard tray should be used with mouse platform on or adjacent to the keyboard platform can be tilted down.
11. A fixed work surface and a fixed keyboard tray should be used.
12. Employees should often take short breaks.

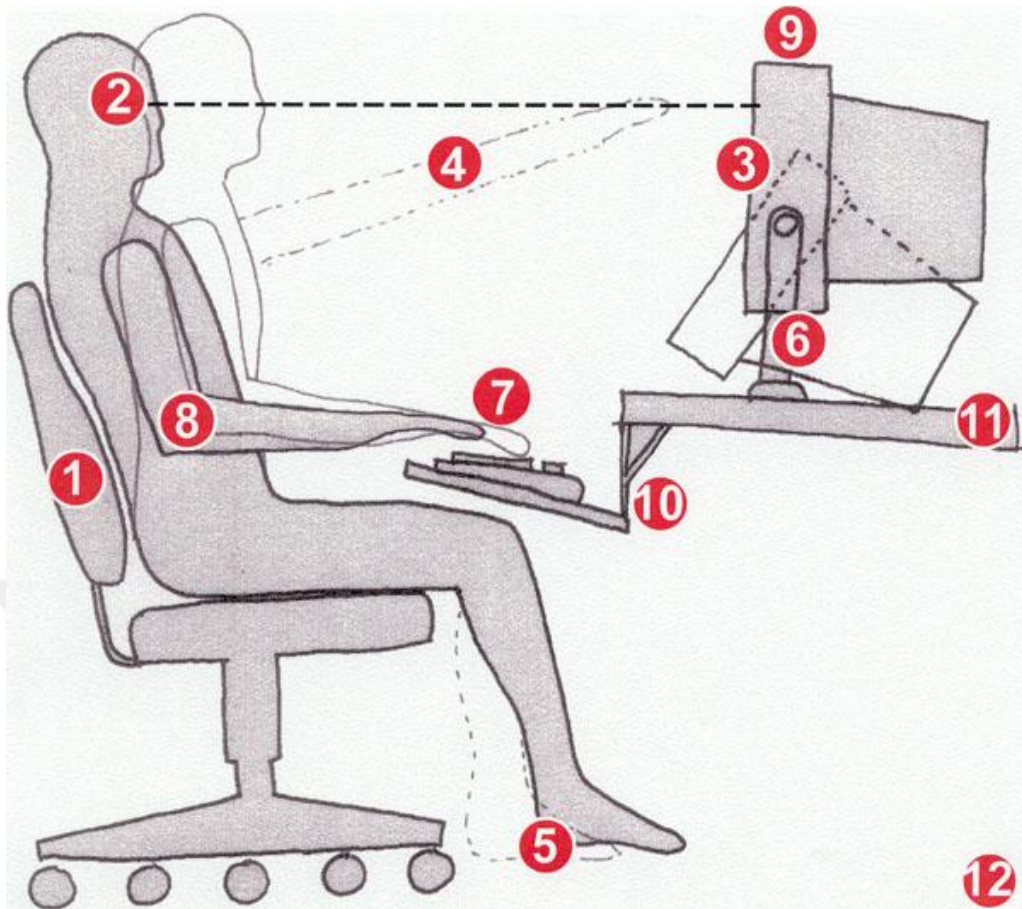


Figure 6.5 Ergonomic computer workstation (Cornell University Ergonomics Web., 2015)

The following information is provided on the evaluation of the survey (USGBC, 2008):

- This survey should be applied to all employees and a response rate of at least 30% should be provided.
- The survey form is shown below in Table 6.5.
- Positive replies of each employee can be summed.

Table 6.3 User survey for ergonomic issues (Cornell University Ergonomics Web, 2014)

User Survey for Ergonomics Issues

How satisfied are you with each of the following:	Are you Satisfied?	
1. Workstation allows me to work in a comfortable, supported neutral posture	No (0)	Yes (1)
2. Workstation allows me to efficiently arrange my work items within easy reach	No (0)	Yes (1)
3. Chair is comfortable, easy to adjust, and provides good back support	No (0)	Yes (1)
4. Keyboard is within easy reach and comfortably positioned for use with flat and straight hands	No (0)	Yes (1)
5. Mouse, trackball or touchpad within easy reach and comfortably positioned for use with my arm close by my side and my hand in flat and straight posture	No (0)	Yes (1)
6. Screen(s) within easy reach and comfortably positioned for viewing without neck bent or twisted	No (0)	Yes (1)
7. Document(s) within easy reach and comfortably positioned near screen for viewing without neck bent or twisted	No (0)	Yes (1)
8. No visible glare on screen(s) or document(s)	No (0)	Yes (1)
9. Sufficient light to comfortably read paper documents	No (0)	Yes (1)
10. Worksurface is at a comfortable working height	No (0)	Yes (1)
11. Adequate leg clearance under worksurface	No (0)	Yes (1)
12. Feet are supported on floor or support surface	No (0)	Yes (1)
13. I never experience frequent neck, back, shoulder, arm, hand or legs discomfort at my workstation	No (0)	Yes (1)
14. Temperature usually is comfortable and indoor air quality is acceptable	No (0)	Yes (1)
15. Background noise and speech privacy level usually is acceptable	No (0)	Yes (1)
TOTAL SCORE (add all of the scores together)		

This survey allows to identify the areas in the workplace where employees need to be improved. The most important advantage of this method is the assessment of both physical and environmental risks. This survey is a subjective evaluation method. The application does not take a long time because it is a short survey. It is also easy to understand for employees and easy to evaluate for the researcher.

6.4.1.2 Cornell Musculoskeletal Discomfort Questionnaire Method.

In this study Turkish version of Cornell Musculoskeletal Discomfort Questionnaire has been used to detect the existing musculoskeletal diseases of blood center laboratory workers. Turkish version of CMDQ was proven cross-cultural adaptation, validity and reliability by Erdiñç et al.,2011 This questionnaire is not used for the diagnosis of a disease but can only be used for the screening of musculoskeletal disorders (Hedge et al.,1999).

Information on age, weight and height and work experience in years are requested at CMDQ. CMDQ examines musculoskeletal disorders in 20 body parts. These 20 body parts are neck, right/left shoulder, upper back, right/left upper arm, lower back, right/left forearm, riht/left wrist, hip/buttocks, right/left thigh, right/left knee, right/left lower leg, right/left foot. CMDQ wants to mark the frequency of feeling of pain, pang, discomfort in the last one week in these 20 body parts. If felt, it should also be marked for discomfort and interference of work. Cornell questionnaire is shown in Figure 6.7.

The diagram below shows the approximate position of the body parts referred to in the questionnaire. Please answer by marking the appropriate box.



	During the last work <u>week</u> , how often did you experience ache, pain, discomfort in:					If you experienced ache, pain, discomfort, how uncomfortable was this?			If you experienced ache, pain, discomfort, did this interfere with your ability to work?		
	Never	1-2 times last week	3-4 times last week	Once every day	Several times every day	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable	Not at all	Slightly interfered	Substantially interfered
Neck	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Shoulder (Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Shoulder (Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Back	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Arm (Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Arm (Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Back	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Forearm (Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Forearm (Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Wrist (Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Wrist (Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hip/Buttocks	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Thigh (Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Thigh (Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Knee (Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Knee (Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Leg (Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Leg (Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Foot (Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Foot (Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure 6.6 Cornell musculoskeletal discomfort questionnaire (Hedge et al.,1999)

Frequency score is sorted and weighted according to the following scale (Hedge et al.,1999):

- Never = 0,
- 1-2 times/week = 1.5,
- 3-4 times/week = 3.5,
- Every day = 5,
- Several times every day = 10.

Discomfort score is sorted and weighted according to the following scale (Hedge et al.,1999):

- Slightly uncomfortable=1,
- Moderately uncomfortable=2,
- Very uncomfortable=3.

Interference score is sorted and weighted according to the following scale (Hedge et al.,1999):

- Not at all=1,
- Slightly interfered=2,
- Substantially interfered=3.

The status of the musculoskeletal disorder is determined according to the score obtained from this scale. (Hedge et al.,1999)

6.4.1.3 Rapid Entire Body Assessment Method

REBA (Rapid Entire Body Assessment) was designed and developed to be sensitive to the types of unpredictable working positions that exist in other service sectors, particularly in the healthcare sector by Hignett and McAtamney. REBA assesses the postural risk of the whole body of the employee by taking into account the human-load interaction in dynamic and static postures. This analysis is also used to assess when an improvement is made, whether the risks of discomfort are reduced before and after development. (Hignett & McAtamney, 2000)

The aims of REBA method are as follows (Hignett & McAtamney, 2000):

- Improving a posture analysis system that is sensitive to risk factors of musculoskeletal system.
- Examining the body by dividing into separate segments with reference to the motion planes.
- Creating a scoring system for muscle movements caused by unstable, static, dynamic postures.
- Indicating the importance of coupling in the handling of loads.
- Giving an action level according to the urgency of risks.
- Necessitating minimal equipment for use.

The REBA method consists of 7 steps (Stanton et al., 2005):

Step 1: Observation of works

Step 2: Selecting the position to be evaluated

Step 3: Scoring the selected posture

Step 4: Processing of points in REBA form

Step 5: Creation of REBA score

Step 6: Determination of action levels for control measures

Step 7: Re-evaluation

In Table 6.4, it is shown that REBA level of risk scale. There are five action levels in REBA (level 0, level 1, level 2, level 3, level 4). REBA scores are categorized according to these five levels. The risk levels of these five action levels are as follows respectively: negligible, low, medium, high, very high. According to these risk levels, action plan is presented.

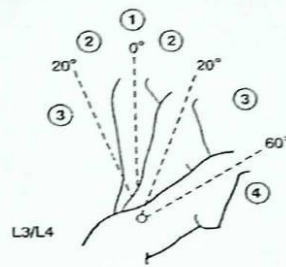
Table 6.4 REBA action levels (Hignett & McAtamney, 2000)

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

In Figure 6.7, it is shown that REBA body part diagrams. In the REBA method, 6 body parts are evaluated. These parts are trunk, neck, legs, upper arms, lower arms and wrist.

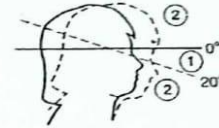
Trunk

Movement	Score	Change score:
Upright	1	+1 if twisting or side flexed
0°–20° flexion 0°–20° extension	2	
20°–60° flexion >20° extension	3	
>60° flexion	4	



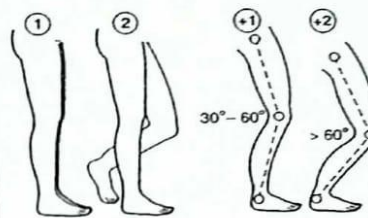
Neck

Movement	Score	Change score:
0°–20° flexion	1	+1 if twisting or side flexed
>20° flexion or in extension	2	



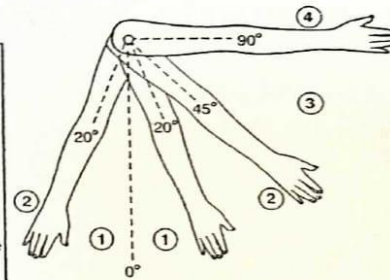
Legs

Position	Score	Change score:
Bilateral weight bearing, walking or sitting	1	+1 if knee(s) between 30° and 60° flexion +2 if knee(s) are >60° flexion (n.b. Not for sitting)
Unilateral weight bearing Feather weight bearing or an unstable posture	2	



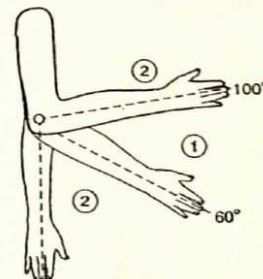
Upper arms

Position	Score	Change score:
20° extension to 20° flexion	1	+1 if arm is: • abducted • rotated
>20° extension 20°–45° flexion	2	
45°–90° flexion	3	+1 if shoulder is raised –1 if leaning, supporting weight of arm or if posture is gravity assisted
>90° flexion	4	



Lower arms

Movement	Score
60°–100° flexion	1
<60° flexion or >100° flexion	2



Wrists

Movement	Score	Change score:
0°–15° flexion/extension	1	+1 if wrist is deviated or twisted
>15° flexion/extension	2	

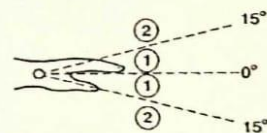


Figure 6.7 REBA body parts diagrams (Hignett & McAtamney, 2000)

The scores vary according to the flexion and extension angles of these body parts. In addition, “change scores” can be added according to body parts’ twisting, flexing etc. Two different tables are used for the evaluation of body parts. (Table A and Table B). In table A, trunk, neck and legs are evaluated. In Table B, upper arms, lower arms and wrist are evaluated. The load / force score is added to table A. The coupling score is added to the Table B. Score A and Score B are obtained according to these additions. From these two different scores, a score is obtained using Table C. This score is called as Score C. Finally, the REBA score is obtained by adding activity score to Score C. These tables and an example of REBA application are shown in section 6.5.2 in detail.

6.4.1.4 Computer Workstation Checklist: OSHA’s VDT Checklist

In OSHA’s VDT Checklist, there are questions about general working conditions, chair, keyboard/ input device, monitor, working area, working accessories and general questions about workstations. Table 6.5 shows the questions for this checklist. The following points have been highlighted regarding the evaluation of this checklist:

- In order for the workstation to be considered ergonomic, all the answer to the question (A-J) in the section on working conditions must be "Yes".
- There must be no more "No" response from two, all of the questions (1-23) in all sections except the working conditions section.

In Occupational Safety and Health Administration web site, there are information on how to evaluate the questions in this checklist (Computer workstations etool, n.d.). Some of the information in the website is related to good working positions, chairs, desks, document holders, keyboards, monitors, pointer/mouse, telephones, wrist/palm supports and workstation environment. This information must be examined before the VDT checklist is evaluated.

Table 6.5 VDT checklist (Computer workstations etool, n.d.)

WORKING CONDITIONS The workstation is designed or arranged for doing VDT tasks so it allows the employee's . . .	Y	N
A. Head and neck to be about upright (not bent down/back).		
B. Head, neck and trunk to face forward (not twisted).		
C. Trunk to be about perpendicular to floor (not leaning forward/backward).		
D. Shoulders and upper arms to be about perpendicular to floor (not stretched forward) and relaxed (not elevated).		
E. Upper arms and elbows to be close to body (not extended outward).		
F. Forearms, wrists, and hands to be straight and parallel to floor (not pointing up/down).		
G. Wrists and hands to be straight (not bent up/down or sideways toward little finger).		
H. Thighs to be about parallel to floor and lower legs to be about perpendicular to floor.		
I. Feet to rest flat on floor or be supported by a stable footrest.		
J. VDT tasks to be organized in a way that allows employee to vary VDT tasks with other work activities, or to take micro-breaks or recovery pauses while at the VDT workstation.		
SEATING The chair . . .	Y	N
1. Backrest provides support for employee's lower back (lumbar area).		
2. Seat width and depth accommodate specific employee (seatpan not too big/small).		
3. Seat front does not press against the back of employee's knees and lower legs (seatpan not too long).		
4. Seat has cushioning and is rounded/ has "waterfall" front (no sharp edge).		
5. Armrests support both forearms while employee performs VDT tasks and do not interfere with movement.		
KEYBOARD/INPUT DEVICE The keyboard/input device is designed or arranged for doing VDT tasks so that . . .	Y	N
6. Keyboard/input device platform(s) is stable and large enough to hold keyboard and input device.		
7. Input device (mouse or trackball) is located right next to keyboard so it can be operated without reaching.		
8. Input device is easy to activate and shape/size fits hand of specific employee (not too big/small).		
9. Wrists and hands do not rest on sharp or hard edge.		

Table 6.5 continues

MONITOR	Y	N
The monitor is designed or arranged for VDT tasks so that . . .		
10. Top line of screen is at or below eye level so employee is able to read it without bending head or neck down/back. (For employees with bifocals/trifocals, see next item.)		
11. Employee with bifocals/trifocals is able to read screen without bending head or neck backward.		
12. Monitor distance allows employee to read screen without leaning head, neck or trunk forward/backward.		
13. Monitor position is directly in front of employee so employee does not have to twist head or neck.		
14. No glare (e.g., from windows, lights) is present on the screen which might cause employee to assume an awkward posture to read screen.		
WORK AREA	Y	N
The work area is designed or arranged for doing VDT tasks so that . . .		
15. Thighs have clearance space between chair and VDT table/keyboard platform (thighs not trapped).		
16. Legs and feet have clearance space under VDT table so employee is able to get close enough to keyboard/input device.		
ACCESSORIES	Y	N
17. Document holder , if provided, is stable and large enough to hold documents that are used.		
18. Document holder , if provided, is placed at about the same height and distance as monitor screen so there is little head movement when employee looks from document to screen.		
19. Wrist rest , if provided, is padded and free of sharp and square edges.		
20. Wrist rest , if provided, allows employee to keep forearms, wrists and hands straight and parallel to ground when using keyboard/input device.		
21. Telephone can be used with head upright (not bent) and shoulders relaxed (not elevated) if employee does VDT tasks at the same time.		
GENERAL	Y	N
22. Workstation and equipment have sufficient adjustability so that the employee is able to be in a safe working posture and to make occasional changes in posture while performing VDT tasks.		
23. VDT Workstation, equipment and accessories are maintained in serviceable condition and function properly.		
PASSING SCORE = "YES" answer on all "working postures" items (A-J) and no more than two "NO" answers on remainder of checklist (1-23).		

The VDT checklist assesses both physical risks and working materials from an ergonomic perspective. It is an advantage for observers because it is easy to use and evaluate. There are many computerized workstations in the laboratory. So, the VDT checklist has a great importance in the evaluation of these stations.

6.4.1.5 Copenhagen Psychosocial Questionnaire Method

Copenhagen Psychosocial Questionnaire Method developed by Kristensen et al. (2005) to assess psychosocial risks. In this study Turkish version of Copenhagen Psychosocial Questionnaire Method (COPSOQ) has been used to detect the psychosocial risks in the laboratory environment. Turkish version of COPSOQ was proven cross-cultural adaptation, validity and reliability by Şahan (2016).

The Copenhagen Psychosocial Questionnaire method is one of the tools available for measuring psychosocial factors. The psychosocial dimensions that it evaluates are: Quantitative Demands, Cognitive Demands, Emotional Demands, Demands for Hiding Emotions, Sensorial Demands, Influence at Work, Possibilities for Development, Degree of Freedom at Work, Meaning of Work, Commitment to the Workplace, Predictability, Role Clarity, Role Conflicts, Quality of Leadership, Social Support, Feedback at Work, Social Relations, Sense of Community, Insecurity at Work, Job Satisfaction.

There are three scales in this method. The dimensions of these 3 scales and the number of questions is shown in Table 6.6. The medium scale has been used in this study. There are 20 psychosocial dimensions and 69 questions in medium scale.

Table 6.6 COPSOQ scale number of questions (Şahan, 2016)

No	COPSOQ scale dimensions	Total Number of Questions		
		Long	Medium	Short
1	Quantitative Demands	7	4	3
2	Cognitive Demands	8	4	-
3	Emotional Demands	3	3	2
4	Demands for Hiding Emotions	2	2	1
5	Sensorial Demands	5	4	-
6	Influence at Work	10	4	3
7	Possibilities for Development	7	4	2
8	Degree of Freedom at Work	4	4	1
9	Meaning of Work	3	3	2
10	Commitment to the Workplace	4	4	2
11	Predictability	2	2	2
12	Role Clarity	4	4	-
13	Role Conflicts	4	4	-
14	Quality of Leadership	8	4	2
15	Social Support	4	4	2
16	Feedback at Work	2	2	2
17	Social Relations	2	2	-
18	Sense of Community	3	3	2
19	Insecurity at Work	4	4	4
20	Job Satisfaction	7	4	4
Total Number of Questions		93	69	34

In Table 6.7, COPSOQ scale dimensions and their meanings are shown. The meanings of each of the 20 psychosocial dimensions in the medium scale are described in Table 6.7.

Table 6.7 COPSOQ Scale Dimensions and Meanings (Şahan, 2016)

Dimension Name	Dimension Meaning
Quantitative Demands	It is used to assess the incompatibility between the amount of time and the amount of work available to fulfill an employee's task.
Cognitive Demands	It is used to assess the cognitive abilities of the employees with the demands expected from them.
Emotional Demands	When the employee has a conflict with their own feelings or with the feelings of other persons, it indicates the demands that they have to deal with.
Demands for Hiding Emotions	It refers to the existence of situations that require employees to hide their feelings from other people in the workplace.
Sensorial Demands	It indicates the level of activity of the senses expected from the employees at work.
Influence at Work	Indicate whether the employees have any influence on the work.
Possibilities for Development	It examines whether employees are able to develop their expertise in the work they do.
Degree of Freedom at Work	It is investigating how effective employees are in determining vacation times, working days and length of working hours
Meaning of Work	It questions employees' thoughts about the purpose and meaning of the work they are doing.
Commitment to the Workplace	It investigates the employees' commitment to the establishment they work with.
Predictability	It examines the situations in which employees encounter uncertainties during operation.

Table 6.7 continues

Role Clarity	There are questions about the contents of the employee's work at the workplace, the expectations and the degree of clarity of his / her duties.
Role Conflicts	It interrogates the causes of conflicts related to the presence of requests contradictory to the nature of the task within the task and the reasons for the conflicts of priority orders of different tasks.
Quality of Leadership	It is questioning the management ability of a supervisor.
Social Support	It is questioning whether the employees can get support from supervisor and co-workers.
Feedback at Work	It indicates whether the employee has feedback about his / her duties
Social Relations	There are questions about the status of social relations in the workplace.
Sense of Community	It gives information about the level of relationship between employees.
Insecurity at Work	There are questions about how employees feel about job insecurity.
Job Satisfaction	It expresses the satisfaction level of employees in terms of various aspects of work.

6.4.2 Formation of the Integrated Structure to Evaluate the Results

In Figure 6.8, the structure of the IERAMCA methodology has been summarized. The purpose of this methodology is to determine a risk level by assessing all the risks of the work being examined. A risk score is obtained by assessing physical, psychosocial and environmental risks. It is also included in the evaluation by comparing employee reports and infirmity records. In this way more reliable and objective assessment is made.

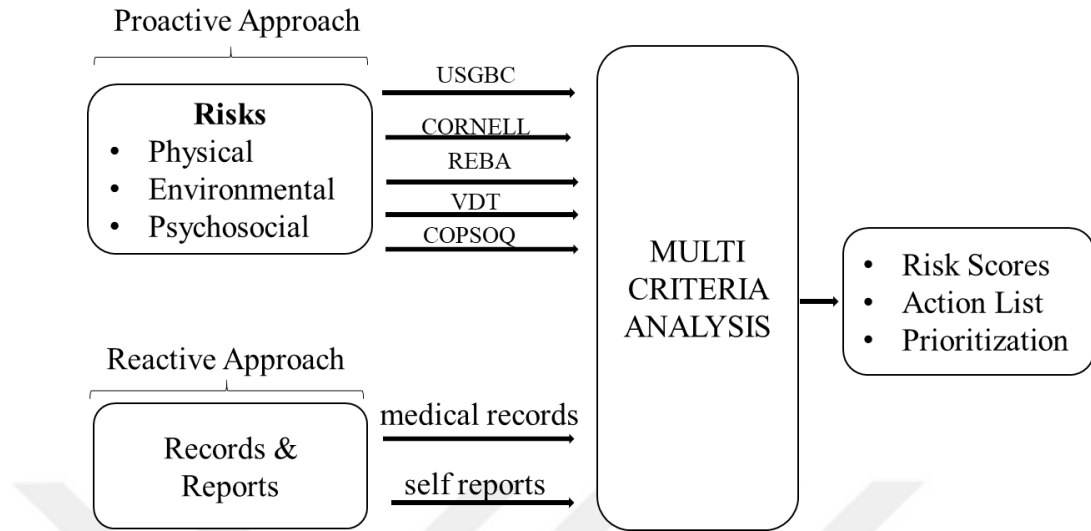


Figure 6.8 Integrated structure of IERAMCA methodology-2

In Figure 6.8, in the formation of the integrated structure to evaluate the results of the ergonomic risk assessment methods, proactive and reactive approaches are used together. Data from two branches is used when creating this integrated methodology. These are two branches: Risks and Reported & Recorded Musculoskeletal System Disorders. Data on risks in the system and data on reported & recorded musculoskeletal system disorders are obtained using ergonomic risk assessment methods and medical records. The methods selected in this study are USGBC, CMDQ, REBA, VDT, and COPSQ. Results obtained from these five ergonomic risk assessment methods are evaluated in a common structure with ANP method. Risk scores are obtained according to the results of evaluation in common structure. Risks are prioritized and action list is created.

6.4.3 Selection of Multi-Criteria Analysis Method that is Suitable for the Structure

These five methods have been selected for the ergonomic risk assessment according to the proposed methodology in the study. As a multi-criteria decision analysis method, The Analytical Network Process (ANP) method has been selected. Considering the features of these five ergonomic risk assessment methods, the most appropriate method is ANP. One of the most significant features of this problem is the dependence between factors. ANP method allows dependency to be taken into account. ANP is well suited to this situation because it evaluates the internal and external relationships of the criteria. ANP method has been selected for these reasons.

6.4.3.1 ANP Method

The Analytical Network Process (ANP) is a multi-criteria decision-making technique developed by Saaty (1996) as a more general approach from the Analytic Hierarchy Process (AHP) approach. The Analytical Network Process is also based on pairwise comparisons. The decision-making criteria and options are based on feedback and dependence among themselves. Therefore, it has emerged as an approach where more complex decision situations can be modeled more accurately. (Saaty, 1996; Saaty, 1999; Saaty, 2003)

AHP provides a hierarchical and unidirectional relationship between decision levels, while ANP allows more complicated relationships (İlgin & Gupta, 2017). ANP allows internal and external dependencies. The dependency between criterion clusters is called external dependency, and the dependency within a cluster is called internal dependency (Niemira & Saaty, 2004).

The ANP method consists of the following steps (Saaty, 1996; Chung et al., 2005; Saaty & Vargas, 2006):

Step 1: Creating of the model and problem structuring

Step 2: Pairwise comparisons and priority vectors

Step 3: Creating of the super matrix

Step 4: Synthesizing the priorities of the criteria and alternatives and choosing the best alternative

There are descriptions of these 4 steps below.

Step 1: Creating of the model and problem structuring: A clear expression of the problem should be provided and a logical system, such as a network, should be established by decision-makers.

Step 2: Pairwise comparisons and priority vectors: The pairs of decision-making elements in each cluster are compared according to their importance in terms of criteria. When making pairwise comparisons, it is necessary to determine and examine the internal dependencies of a cluster among the criteria. The effect of each element on other elements can be expressed by eigenvectors. Relative importance values in comparison are determined by the scale of Saaty in Table 6.8. In this table, score 1 means that there is no superiority between the two elements. Score 9 means that an element (row element of matrix) has highly importance according to other (column element of matrix).

Table 6.8 Comparison scale (Saaty, 1990)

Importance level	Description
1	Equal importance
3	Less important
5	Quite important
7	Very important
9	Highly important
2,4,6,8	Intermediate values
Inverse Values	Comparison of the second alternative with the first alternative in terms of the same criterion

Step 3: Creating of the super matrix: To attain general priorities in systems with internal dependent effects, general priority vectors must be entered in appropriate matrix columns. In fact, the super matrix is a separated matrix, and each part represents

the relationship between the two clusters. To obtain limit super matrix and to reach the convergence, the super matrix should be raised to $2k+1$ power. k is considered arbitrarily large number. Each group in the super matrix must be normalized to obtain the final priorities of all elements in the matrix.

Step 4: Synthesizing the priorities of the criteria and alternatives and choosing the best alternative: If the super matrix covers the entire network, the weights of the alternatives are indicated in the column for alternatives concerned with the normalized super matrix. That is, if the super matrix includes only the associated groups, further calculation is required to reach the general priority of the alternatives. The choice of alternative with the greatest general priority should be carried out.

Pairwise comparison is applied to the criteria and alternatives in ANP method and this comparison is based on scale of ANP. It is not right to determine the degree of superiority in pairwise comparison by a single decision maker. The opinions of those who have sufficient knowledge on the subject and who are involved in the study should be consulted. More objective comparison can be made in this way. (Timor, 2011)

For these reasons, the group decision-making process has been applied in the ANP application in this study. In the group decision making process, it is one of the points that makes it difficult to allow the evaluation of multiple people's ideas in the pairwise comparison process. Because every member of the study group will be judged on all the criteria and a consensus must be made to obtain a single judgment from these judgments. The geometric mean method is commonly used to ensure consensus between judgments of group members. (Kuruüzüm & Atsan, 2001) For this reason, geometric mean is used for ANP group decision in this study.

6.4.4 Adapting Integrated Ergonomic Risk Assessment into Multi-Criteria Analysis Method

Integrated ergonomic risk assessment is adapted into multi-criteria analysis method in this section. Ergonomic risk assessment methods are evaluated by multi criteria criteria decision making method. This section contains the following titles: formation of multi-criteria analysis model and determination of weights.

6.4.4.1 Formation of Multi-Criteria Analysis Model

When creating the ANP model, criteria and sub-criteria should be determined. The determination of internal and external relations between criteria is important. There are four criteria. Total of 13 sub-criteria have been determined for these four criteria in this study. There are descriptions of these criteria below:

Criterion 1: Types of Risks: In the development of musculoskeletal diseases many different factors play role, such as physical and biomechanical factors, environmental, organizational and psychosocial factors, individual and personal factors. They may play a role in the development of the disease as well as in various compositions. (İSG, 2007)

The types of risks that the five methods used in this study take into account are given below and these risk types are defined as sub-criteria.

- Physical (P)
- Environmental (E)
- Psychosocial (Ps)

Criterion 2: Usage: It is very important that an ergonomic risk assessment tool has certain features in terms of its use. These properties have been determined as duration, expertise requirement, convenience in practice in this study. These 3 features constitute the sub criteria of the usage criterion.

A risk assessment method should be valid, reliable equalization of risk factors, generalizable standard tool for the regulators. Methods should be quick and easy to

implement. Furthermore, methods should be clear to those who practice and easy to learn. (Kesiktaş,2007)

- Duration (D)
- Expertise requirement (Er)
- Convenience in practice (C)

Criterion 3: Focus: In many studies, subjective methods and observational methods are often used. Subjective methods are based on person declaration and have been defined as sub criteria as “person-based”. Observational methods are generally applied when employee working and therefore, they have been defined as work criteria as sub criteria as “work-based”.

In an employee's physical workload assessments, only the observer's subjective assessment is not sufficient and the observation methods are less sensitive than evaluating dynamic work situations (Kesiktaş, 2007). Subjective methods should definitely be used in evaluations.

- Work-based (Wb)
- Person-based (Pb)

Criterion 4: Perfection: It is very important that an ergonomic risk assessment tool is superior in terms of perfection. The sub-criteria in the perfection criterion have been determined as follows: Evaluation of body parts, Evaluation of work materials, Contribution to preventive measures, Applicability to all job-steps and workstations, Confuse situations outside of work (Non-confiscation of non-business (private) life risks during evaluation).

An ergonomic risk assessment method must be easy to learn and be limited to filling the form. One of the most important qualities that an evaluation method should possess is its uniqueness to task and work. Also, it should not contain unnecessary information collection (Non-confiscation of non-business (private) life risks during evaluation). (Kesiktaş, 2007)

It is important that the tools and equipment used when doing work are designed according to ergonomics principles. Many hand tools and equipment are suitable for a certain period of time, not for long periods of repeated use. Attention should be paid to ergonomic features when new equipment is purchased at the workplace (Ayanoglu,2007)

- Evaluation of body parts (Eb)
- Evaluation of work materials (Ew)
- Contribution to preventive measures (Cp)
- Applicability to all job-steps and workstations (A)
- Confuse situations outside of work (Cs): Non-confiscation of non-business (private) life risks during evaluation

Internal and external relations between the criteria have been determined and a matrix of bilateral relations has been established. Internal and external relations between criteria are shown in Table 6.9. Cells in this table show a direct relationship between the criterion i and the criterion j. If the criterion i affects the criterion j, a (●) is put to the cell a_{ij} in the matrix. If a cell in the table is empty, it means that there is no relation.

Table 6.9 Internal and external relations between criteria

		Types of Risks			Usage			Focus		Perfection				
		P	E	Ps	D	Er	C	Wb	Pb	Eb	Ew	Cp	A	Cs
Types of Risks	P									•		•	•	•
	E											•	•	•
	Ps											•	•	•
Usage	D													
	Er				•									
	C				•									
Focus	Wb				•	•	•			•	•	•	•	•
	Pb				•	•	•			•	•			•
Perfection	Eb				•	•	•					•		
	Ew				•	•	•					•		
	Cp													
	A				•	•	•					•		
	Cs					•	•							

There is an external relationship between “types of risks” criterion and “perfection” criterion. These relations are as follows on the basis of sub-criteria.

- Physical Risks - Evaluation of body parts: The methods that evaluate the physical risks can also evaluate the body parts.
- Physical, Environmental, Psychosocial Risks - Contribution to preventive measures: Some methods of assessing such risks determine an urgency level according to the result score and provide an action level. In this way, it contributes to the observer's taking preventive measures.
- Physical, Environmental, Psychosocial Risks - Applicability to all job-steps and workstations: Some methods for these risk types can be applied to all job-steps and workstations. For example, REBA is designed to be sensitive to the type of unexpected working postures found in especially healthcare and other service sectors and this method provides the need for a practitioner to use in the field (Hignett & McAtamney, 2000).
- Physical, Environmental, Psychosocial Risks - Confuse situations outside of work: There are many subjective judgment methods that evaluate such risk

groups. One of the major disadvantages of most of the subjective judgment methods is the confusion of private life risks.

There are internal relations between the sub-criteria of the “usage” criterion.

- Expertise requirement, Convenience in practice - Duration: In the use of an ergonomic risk assessment method, the expertise requirement and convenience in practice affect the application duration of these methods.

There is an external relationship between “focus” criterion and “usage” criterion.

- Work-based, Person-based – Duration: The application duration of an ergonomic risk assessment method may also vary depending on whether it is observational or subjective.
- Work-based, Person-based - Expertise requirement: The expertise requirement for an ergonomic risk assessment method may vary depending on whether it is observational or subjective.
- Work-based, Person-based - Convenience in practice: The convenience in practice of the ergonomic risk assessment method can also vary depending on whether it is observational or subjective.
- Work-based, Person-based - Evaluation of body parts: The evaluation of the body part depends on the ergonomic risk assessment method. Evaluated body parts vary according to observational and subjective methods.
- Work-based, Person-based - Evaluation of work materials: Evaluation of working materials for ergonomic convenience varies according to whether the method is observational or subjective.
- Work-based- Contribution to preventive measures: Some observational methods determine an urgency level according to the result score and provide an action level. In this way, it contributes to the observer's taking preventive measures.

- Work-based - Applicability to all job-steps and workstations: Some observational methods that examine the work can be applied to all job-steps and workstations.
- Work-based, Person-based - Confuse situations outside of work: Confusion of private life risks in the evaluation depends on whether the method is observational or subjective.

There are internal relations between the sub-criteria of the “perfection” criterion.

- Evaluation of body parts, Evaluation of work materials, Applicability to all job-steps and workstations - Contribution to preventive measures: There are differences in the ability to determine the action levels of ergonomic risk assessment methods with these perfection characteristics.

There is an external relationship between “perfection” criterion and “usage” criterion.

- Evaluation of body parts, Evaluation of work materials, Applicability to all job-steps and workstations – Duration: Some perfection characteristics of the methods affect the application duration.
- Evaluation of body parts, Evaluation of work materials, Applicability to all job-steps and workstations, Confuse situations outside of work - Expertise requirement: The expertise requirement varies in the methods with these perfection characteristics.
- Evaluation of body parts, Evaluation of work materials, Applicability to all job-steps and workstations, Confuse situations outside of work - Convenience in practice: The convenience in practice varies in the methods with these perfection characteristics.

ANP model of the problem is given in Figure 6.9. The network model in Figure 6.9 has been created using the Super Decisions software. In the network structure in Figure 6.9, there is a hierarchical structure except for internal and external relations between criteria. This network structure has a goal, criteria and alternatives. The goal of this ANP model is to determine the weights of five methods selected for ergonomic risk assessment. Four criteria have been determined for this model. There are thirteen sub-criteria of these four criteria. The alternatives in the model are five ergonomic risk

assessment methods. These are REBA, VDT, USGBC, CMDQ and COPSOQ. The appearance of internal and external relations in the network structure is as in Figure 6.9.



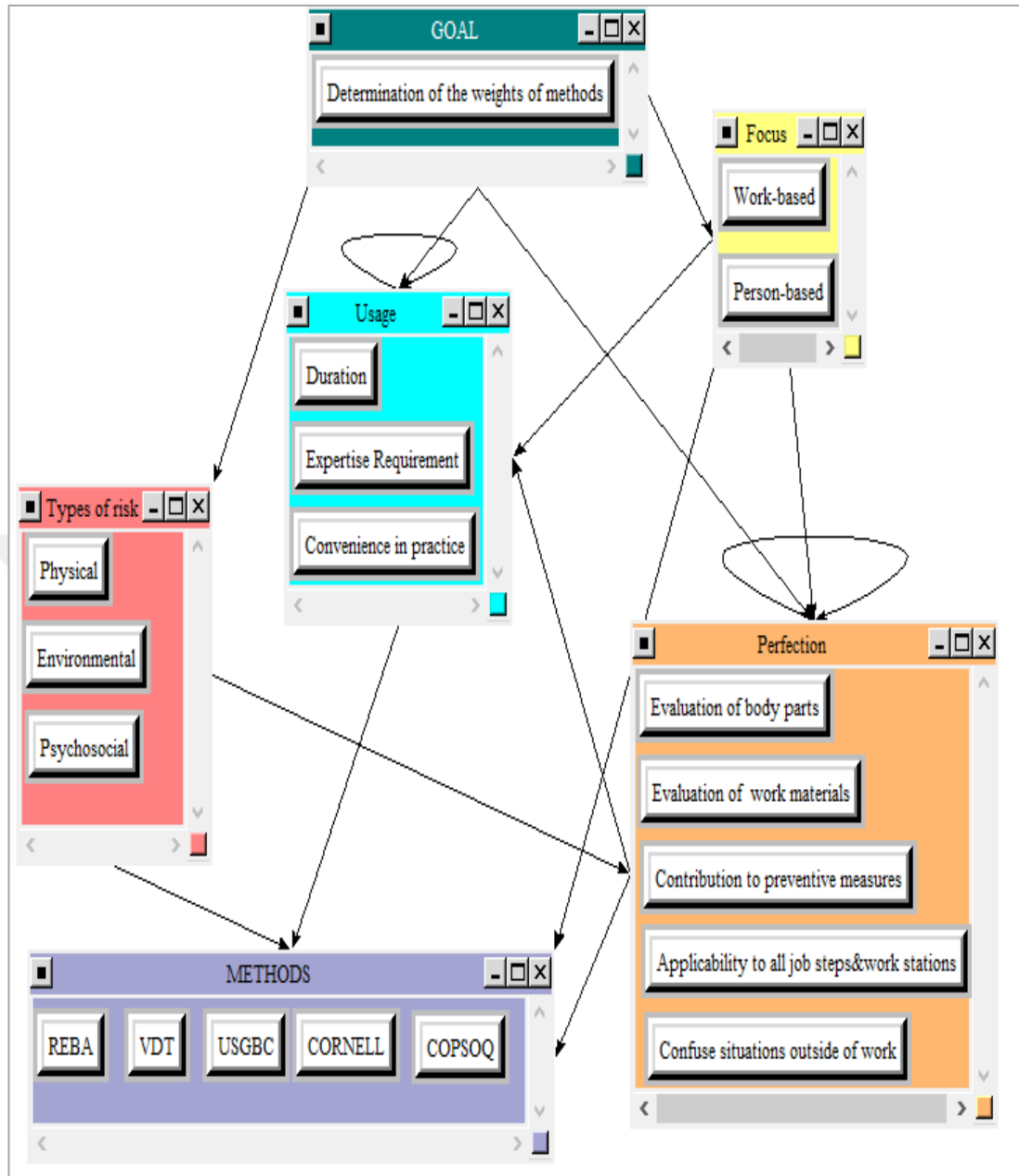


Figure 6.9 The ANP model

In this section, the creation of the ANP model selected as the multi-criteria decision making method is described. The goal, criteria and alternatives of the problem have been determined. Internal and external relations between the criteria are explained.

6.4.4.2 Determination of weights

In this section, the processes required to determine the weights of the alternatives have been carried out. In Table 6.10, an example of pairwise comparison according to the group decision method with person-based node and usage cluster is given. All node and cluster comparisons shown below have been made in consultation with the experts for each of them as in Table 6.10. Table 6.10 gives an example of one of these comparisons. In this study, all pairwise comparisons in ANP application have been made by group decision method. The decisions of the five experts have been consulted. Three of these experts are not personnel of the institution of application. Two of these experts are personnel of the institution of application.

All node and cluster comparisons in the network have been made according to the group decision method. In this method, a result is obtained by taking the geometric mean of the experts' decisions. In Table 6.10, columns E1 (Expert1), E2 (Expert2), E3 (Expert3), E4 (Expert4) and E5 (Expert5) indicate expert decisions. In the “geometric mean” column, there are geometric means of the decisions. In the “consensus” column, the geometric means are expressed according to the scale. A form has been prepared for experts to make pairwise comparisons easier. All comparisons in this form have been expressed as a question. In this form, questions and criteria for pairwise comparisons are expressed differently, so that experts can better understand them. An example of these different expressions can be found in Table 6.10. For example, in this table, the duration and expertise requirement nodes in the usage cluster are expressed as “less time to get the methods application” and “less expertise requirement in the implementation of the method”, respectively. In addition, in this table, the “person-based” node in the usage cluster is expressed as “subjective assessment methods”. This descriptive form of expression is more understandable for the experts in the group decision method.

Table 6.10 Sample comparison of the group decision

	E1	E2	E3	E4	E5	geometric mean	consensus	
In the subjective assessment methods, compare the criteria related to the usage of methods to the level of importance.								
Convenience in practice	1	3	3	6	8	3.365865436	3	Less time to get the method's application
Convenience in practice	0.3333	0.5	0.2	2	0.143	0.39424132	1/3	Less expertise requirement in the implementation of the method
Less time to get the method's application	0.5	0.25	0.14	0.25	0.143	0.229578275	1/4	Less expertise requirement in the implementation of the method

For all node and cluster comparisons, values have been determined by group decision and these values have been entered in Super Decisions software. The screenshot of each pairwise comparison is given in the following figures. As shown in the figures below, the red numbers represent inverse values. In other words, if the factor on the left is more important than the factor on the right, the selection is made from the blue region. If the factor on the right is more important than the factor on the left, the selection is made from the red region.

In this section, node and cluster pairwise comparisons are given. The consistency of all pairwise comparisons have been calculated. For all inconsistency values of pairwise comparisons are less than 0.1 (10%), we can say that all comparisons are consistent.

In Figure 6.10, in terms of “Determination of the weights of methods” node, there is a comparison of elements of “Perfection” cluster.

Comparisons wrt "Determination of the weights of methods" node in "Perfection" cluster
Applicability to all job steps&work stations is moderately more important than confuse situati~

1. Applicability to~	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	confuse situati~
2. Applicability to~	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Contribution to~
3. Applicability to~	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of ~
4. Applicability to~	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of b~
5. confuse situati~	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Contribution to~
6. confuse situati~	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of ~
7. confuse situati~	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of b~
8. Contribution to~	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of ~
9. Contribution to~	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of b~
10. Evaluation of ~	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of b~

Figure 6.10 Comparison of determination of the weights of methods node and perfection cluster

The inconsistency ratio of the pairwise comparison in Figure 6.10 is 0.05453.

In Figure 6.11, in terms of “Determination of the weights of methods” node, there is a comparison of elements of “Types of risk” cluster.

Comparisons wrt "Determination of the weights of methods" node in "Types of risk" cluster

Physical is moderately more important than Environmental

1. Environmental	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Physical	
2. Environmental	>=9.5	9	8	7	6	5	4	3	2		1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Psychosocial
3. Physical	>=9.5	9	8	7	6	5	4	3	2			2	3	4	5	6	7	8	9	>=9.5	No comp.	Psychosocial

Figure 6.11 Comparison of determination of the weights of methods node and types of risk cluster

The inconsistency ratio of the pairwise comparison in Figure 6.11 is 0.01759.

In Figure 6.12, in terms of “Determination of the weights of methods” node, there is a comparison of elements of “Usage” cluster.

Graphical	Verbal	Matrix	Questionnaire	Direct																	
Comparisons wrt "Determination of the weights of methods" node in "Usage" cluster																					
Convenience in practice is moderately more important than Duration																					
1. Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Duration
2. Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requi~
3. Duration	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requi~

Figure 6.12 Comparison of determination of the weights of methods node and usage cluster

The inconsistency ratio of the pairwise comparison in Figure 6.12 is 0.01759.

In Figure 6.13, in terms of “Determination of the weights of methods” node, there is a comparison of elements of “Focus” cluster.

Graphical	Verbal	Matrix	Questionnaire	Direct																	
Comparisons wrt "Determination of the weights of methods" node in "Focus" cluster																					
Work-based is moderately more important than Person-based																					
1. Person-based	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Work-based

Figure 6.13 Comparison of determination of the weights of methods node and focus cluster

The inconsistency ratio of the pairwise comparison in Figure 6.13 is 0.00.

In Figure 6.14, in terms of “Person-based” node, there is a comparison of elements of “Usage” cluster.

Graphical	Verbal	Matrix	Questionnaire	Direct																	
Comparisons wrt "Person-based" node in "Usage" cluster																					
Convenience in practice is moderately more important than Duration																					
1. Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Duration
2. Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requi~
3. Duration	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requi~

Figure 6.14 Comparison of person-based node and usage cluster

The inconsistency ratio of the pairwise comparison in Figure 6.14 is 0.07069.

In Figure 6.15, in terms of “Person-based” node, there is a comparison of elements of “Perfection” cluster.

Comparisons wrt "Person-based" node in "Perfection" cluster																						
confuse situations outside of work is equally to moderately more important than Evaluation of ~																						
1. confuse situati~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of ~	
2. confuse situati~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of b~	
3. Evaluation of ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of b~	

Figure 6.15 Comparison of person-based node and perfection cluster

The inconsistency ratio of the pairwise comparison in Figure 6.15 is 0.

In Figure 6.16, in terms of “Work-based” node, there is a comparison of elements of “Perfection” cluster.

Comparisons wrt "Work-based" node in "Perfection" cluster																								
Applicability to all job steps&work stations is moderately more important than confuse situatio																								
1.	Applicability t~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	confuse situati~		
2.	Applicability t~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Contribution to~		
3.	Applicability t~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of ~		
4.	Applicability t~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of b~		
5.	confuse situati~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Contribution to~		
6.	confuse situati~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of ~		
7.	confuse situati~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of b~		
8.	Contribution to~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of ~		
9.	Contribution to~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of b~		
10.	Evaluation of ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Evaluation of b~		

Figure 6.16 Comparison of work-based node and perfection cluster

The inconsistency ratio of the pairwise comparison in Figure 6.16 is 0.02.

In Figure 6.17, in terms of “Work-based” node, there is a comparison of elements of “Usage” cluster.

Comparisons wrt "Work-based" node in "Usage" cluster																						
Expertise Requirement is equally to moderately more important than Duration																						
1.	Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Duration
2.	Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requi~
3.	Duration	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requi~

Figure 6.17 Comparison of work-based node and usage cluster

The inconsistency ratio of the pairwise comparison in Figure 6.17 is 0.01759.

In Figure 6.18, in terms of “Applicability to all job-steps and workstations” node, there is a comparison of elements of “Usage” cluster.

Comparisons wrt "Applicability to all job steps&work stations" node in "Usage" cluster																								
Expertise Requirement is equally to moderately more important than Duration																								
1. Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Duration			
2. Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requi~			
3. Duration	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requi~			

Figure 6.18 Comparison of applicability to all job-steps node and workstations node and usage cluster

The inconsistency ratio of the pairwise comparison in Figure 6.18 is 0.01759.

In Figure 6.19, in terms of “Evaluation of work materials” node, there is a comparison of elements of “Usage” cluster.

Comparisons wrt "Evaluation of work materials" node in "Usage" cluster																						
Expertise Requirement is equally to moderately more important than Duration																						
1. Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Duration	
2. Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requi~	
3. Duration	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requi~	

Figure 6.19 Comparison of evaluation of work materials node and workstations node and usage cluster.

The inconsistency ratio of the pairwise comparison in Figure 6.19 is 0.05156.

In Figure 6.20, in terms of “Evaluation of body parts” node, there is a comparison of elements of “Usage” cluster.

Comparisons wrt "Evaluation of body parts" node in "Usage" cluster																								
Expertise Requirement is equally to moderately more important than Duration																								
1.	Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Duration		
2.	Convenience in ~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requirement		
3.	Duration	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Expertise Requirement		

Figure 6.20 Comparison of evaluation of body parts node and usage cluster

The inconsistency ratio of the pairwise comparison in Figure 6.20 is 0.01759.

In Figure 6.21, in terms of “Environmental” node, there is a comparison of elements of “Perfection” cluster.

Comparisons wrt "Environmental" node in "Perfection" cluster																			
Contribution to preventive measures is equally to moderately more important than Applicability																			
1. Applicability t~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
2. Applicability t~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
3. confuse situati~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5

Figure 6.21 Comparison of environmental node and perfection cluster

The inconsistency ratio of the pairwise comparison in Figure 6.21 is 0.01759.

In Figure 6.22, in terms of “Physical” node, there is a comparison of elements of “Perfection” cluster.

Comparisons wrt "Physical" node in "Perfection" cluster																			
Contribution to preventive measures is equally to moderately more important than confuse situati~																			
1. Applicability t~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
2. Applicability t~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
3. Applicability t~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
4. confuse situati~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
5. confuse situati~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
6. Contribution to~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5

Figure 6.22 Comparison of physical node and perfection cluster

The inconsistency ratio of the pairwise comparison in Figure 6.22 is 0.02271.

In Figure 6.23, in terms of “Psychosocial” node, there is a comparison of elements of “Perfection” cluster.

Comparisons wrt "Psychosocial" node in "Perfection" cluster																			
Contribution to preventive measures is equally to moderately more important than confuse si																			
1. Applicability t~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
2. Applicability t~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
3. confuse situati~	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5

Figure 6.23 Comparison of psychosocial node and perfection cluster

The inconsistency ratio of the pairwise comparison in Figure 6.23 is 0.05156.

In Figure 6.24, in terms of “Person-based” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "Person-based" node in "METHODS" cluster																			
COPSOQ is equally as important as CORNELL																			
1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5

Figure 6.24 Comparison of person-based node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.24 is 0.

In Figure 6.25, in terms of “Person-based” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "Work-based" node in "METHODS" cluster																			
COPSOQ is equally as important as CORNELL																			
1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5

Figure 6.25 Comparison of work-based node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.25 is 0.07721.

In Figure 6.26, in terms of “Applicability to all job-steps and workstations” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "Applicability to all job steps&work stations" node in "METHODS" cluster
COPSOQ is equally as important as CORNELL

1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	CORNELL
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT

Figure 6.26 Comparison of applicability to all job-steps and workstations node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.26 is 0.07305.

In Figure 6.27, in terms of “Confuse situations outside of work” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "confuse situations outside of work" node in "METHODS" cluster
COPSOQ is very strongly more important than CORNELL

1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	CORNELL
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT

Figure 6.27 Comparison of confuse situations outside of work node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.27 is 0.08351.

In Figure 6.28, in terms of “Contribution to preventive measures” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "Contribution to preventive measures" node in "METHODS" cluster
COPSOQ is equally as important as CORNELL

1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	CORNELL
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT

Figure 6.28 Comparison of contribution to preventive measures node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.28 is 0.

In Figure 6.29, in terms of “Evaluation of work materials” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "Evaluation of work materials" node in "METHODS" cluster
COPSOQ is equally as important as CORNELL

1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	CORNELL
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT

Figure 6.29 Comparison of evaluation of work materials node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.29 is 0.08582.

In Figure 6.30, in terms of “Evaluation of body parts” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "Evaluation of body parts" node in "METHODS" cluster
CORNELL is extremely more important than **COPSOQ**

1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	CORNELL
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDI
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDI
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDI
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDI

Figure 6.30 Comparison of evaluation of body parts node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.30 is 0.09272.

In Figure 6.31, in terms of “Environmental” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "Environmental" node in "METHODS" cluster
COPSOQ is equally as important as **CORNELL**

1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	CORNELL
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDI
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDI
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDI
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDI

Figure 6.31 Comparison of environmental node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.31 is 0.

In Figure 6.32, in terms of “Physical” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "Physical" node in "METHODS" cluster
CORNELL is extremely more important than **COPSOQ**

1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	CORNELL
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT

Figure 6.32 Comparison of physical node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.32 is 0.05923.

In Figure 6.33, in terms of “Psychosocial” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "Psychosocial" node in "METHODS" cluster
COPSOQ is extremely more important than **CORNELL**

1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	CORNELL
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT

Figure 6.33 Comparison of psychosocial node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.33 is 0.

In Figure 6.34, in terms of “Duration” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "Duration" node in "METHODS" cluster
CORNELL is moderately more important than COPSOQ

1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	CORNELL
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT

Figure 6.34 Comparison of duration node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.34 is 0.09012.

In Figure 6.35, in terms of “Expertise requirement” node, there is a comparison of elements of “Methods” cluster.

Comparisons wrt "Expertise Requirement" node in "METHODS" cluster
COPSOQ is equally as important as CORNELL

1. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	CORNELL
2. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
3. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
4. COPSOQ	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
5. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	REBA
6. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
7. CORNELL	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
8. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	USGBC
9. REBA	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT
10. USGBC	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	VDT

Figure 6.35 Comparison of expertise requirement node and methods cluster

The inconsistency ratio of the pairwise comparison in Figure 6.35 is 0.0898.

Node comparisons and inconsistency rates are given above. There are the cluster comparisons below. Inconsistency rates of pairwise comparisons are also given. For all inconsistency values of pairwise comparisons in clusters are less than 0.1 (10%), we can say that all comparisons are consistent.

The inconsistency ratio of the pairwise comparison in Figure 6.36 is 0.06094.

2. Cluster comparisons with respect to GOAL

Graphical Verbal Matrix Questionnaire Direct

Types of risk is strongly more important than Usage

1.	Focus	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Perfection
2.	Focus	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Types of risk
3.	Focus	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Usage
4.	Perfection	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Types of risk
5.	Perfection	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Usage
6.	Types of risk	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Usage

Figure 6.36 Cluster comparisons with respect to goal

The inconsistency ratio of the pairwise comparison in Figure 6.37 is 0.05156.

2. Cluster comparisons with respect to Perfection

Graphical Verbal Matrix Questionnaire Direct

METHODS is extremely more important than Perfection

1.	METHODS	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Perfection
2.	METHODS	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Usage
3.	Perfection	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Usage

Figure 6.37 Cluster comparisons with respect to perfection

The inconsistency ratio of the pairwise comparison in Figure 6.38 is 0.00

METHODS is extremely more important than Perfection

1.	METHODS	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Perfection
----	---------	-------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	-------	----------	------------

Figure 6.38 Cluster comparisons methods and perfection

The inconsistency ratio of the pairwise comparison in Figure 6.39 is 0.00

METHODS is extremely more important than Usage

1.	METHODS	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Usage
----	---------	-------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	-------	----------	-------

Figure 6.39 Cluster comparisons methods and usage

The inconsistency ratio of the pairwise comparison in Figure 6.40 is 0.05156.

2. Cluster comparisons with respect to Focus

Graphical Verbal Matrix Questionnaire Direct

METHODS is extremely more important than Perfection

1. METHODS	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Perfection
2. METHODS	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Usage
3. Perfection	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	Usage

Figure 6.40 Cluster comparisons with respect to focus

All node and cluster pairwise comparisons are made. All pairwise comparison results are consistent. After the completion of the pairwise comparisons, using the Super Decisions software, the limit super matrix has been obtained. According to the results obtained from the program, the weights of five ergonomic risk assessment methods have been obtained. The weights of the methods are as shown in Figure 6.41.

In Figure 6.41, there are weights of five risk assessment methods:

- The weight of the COPSOQ method is 0.12152.
- The weight of the CORNELL method is 0.14777.
- The weight of the REBA method is 0.32561.
- The weight of the USGBC method is 0.23952.
- The weight of the VDT method is 0.13565.

Normalized Priorities

COPSOQ		0.15152
CORNELL		0.14770
REBA		0.32561
USGBC		0.23952
VDT		0.13565

Figure 6.41 Methods weights

The weights of five ergonomic risk assessment methods have been determined by ANP method. The importance of weights is as follows: REBA, USGBC, COPSOQ, CORNELL, VDT.



6.5 Phase 5: Application of Methods in IERAMCA Methodology Separately

In this section, the application of integrated ergonomic risk assessment with multi-criteria analysis methodology is described. Data collection, Method usage and Result evaluation sections are available. The data collection section contains socio-demographic information of laboratory technicians. This section also describes the collection of data required to apply selected ergonomic risk assessment methods. The method usage section describes the use of the selected methods separately. In the result evaluation section, the results of evaluation of these methods are given separately.

6.5.1 Data collection

This section describes the collection of data required to apply five ergonomic risk assessment methods. Data on the sociodemographic information of the laboratory technicians are also presented in this section. These data have been collected with the help of on-site observations and with the help of questionnaires. In addition, some information has been obtained about the laboratory technicians in consultation with the supervisor of the laboratory. Additionally, infirmary records have been reached. Data in the infirmary records have been also taken into account. Data have been confirmed in consultation with the workplace health and safety unit.

So, in this study, data collection has been done in different ways. Firstly, the data have been obtained using the observer perspective. Then, the data related to the declaration of the person have been collected by subjective assessment methods. Except for both observational and subjective methods, existing records have been used. The opinions of the doctors in the workplace health and safety unit, and the infirmary records have been also evaluated. In this way, the study is far from subjectivity and the objectivity of the study is ensured. The data obtained are as follows. 15 of the 18 laboratory technicians have been volunteered for this study. Some sociodemographic information has been obtained with employees' own notifications. Sociodemographic information belonging to the technicians is given in Table 6.11 and Table 6.12 with the details. 47% of the laboratory technicians who were monitored are female and 53% of the technicians are male. The values of the socio-demographic information determined according to the information received from the employees are

expressed in the 95% confidence interval in Table 6.11. Average age, weight, height, Body Mass Index (BMI), work experience in years of technicians are respectively 37.4 ± 4.37 , 73.07 ± 2.86 kg, 170 ± 8.08 cm, 25.185 ± 2.67 , 12.539 ± 3.753 years.

Table 6.11 Sociodemographic information according to employee statements-1

Sociodemographic information of employees	95% Confidence Interval for Mean $\pm$ Standard deviation
Age	37.4 ± 4.37
Weight (kg)	73.07 ± 2.86
Height (cm)	170 ± 8.08
BMI	25.185 ± 2.67
work experience in years	12.539 ± 3.753

Table 6.12 contains information on gender, age, BMI Range, marital status, presence of children, work experience in years, educational status, job accident status, presence of chronic illness and presence of night working of the employees.

Table 6.12 Sociodemographic information according to employee statements-2

Gender	Count	Prevalence(%)
Females	7	47
Males	8	53
Age		
30-34	3	20
35-39	9	60
40-44	2	13
≥ 45	1	7
BMI Range		
18 – 24.99 (normal)	7	47
25 – 29.99 (overweight)	8	53
Marital Status		
Married	10	67
Single	5	33
Presence of Children		
Yes	10	67
No	5	33
Work Experience in Years		
5-9	2	14.3
10-14	10	71.4
15-19	2	14.3

Table 6.12 continues

>20	1	7
Educational Status		
High School	2	13
College and upper	13	87
Job Accident Status		
Yes	8	53.3
No	7	46.7
Presence of Chronic Illness		
Yes	9	60
No	6	40
Night Working		
Yes	14	93.3
No	1	6.7

Nine employees have chronic disease diagnosed by a doctor. Five of these nine employees have more than one chronic illness. Chronic diseases that employees have are divided into 8 categories: hypertension, asthma, bronchitis, cancer, diabetes, rheumatism (bone erosion, knee-back pain, sciatica, lime), mental illness (depression, anxiety, schizophrenia, addiction, etc.) and other diseases. Figure 6.42 shows the frequency of illness among employees. 19% of the diseases employees have are musculoskeletal disorders. 40% of these diseases are the inconveniences that may arise from psychosocial risks.

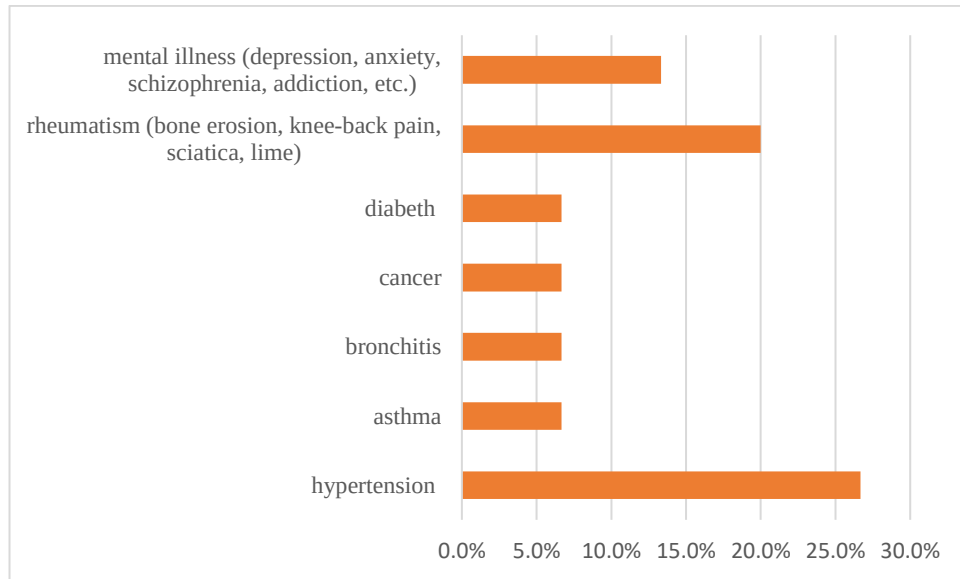


Figure 6.42 Frequency of illness among employees

Eight employees have been involved in work accidents in the past year. Job accidents that employees involved are divided into 8 categories: fall/injury, piece/material drop, entering foreign object to eyes, accidents from machines, accidents of hand tools, electric accidents, crushing/jamming, accidents resulting from touching harmful and dangerous items. Job accidents employees and accident percentages are indicated in Figure 6.43.

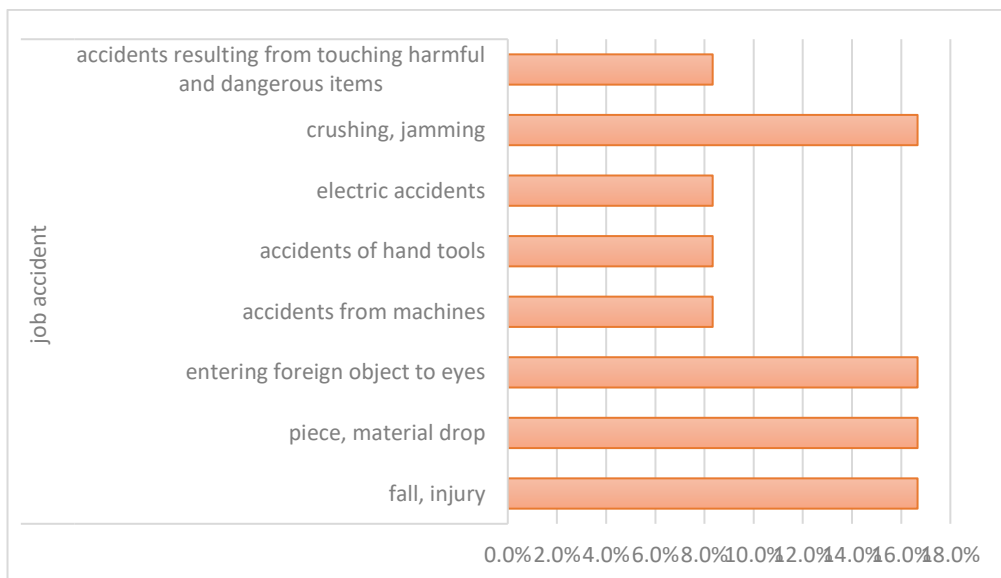


Figure 6.43 Job accident status

The percentages of accidents in the laboratory are as follows: fall/injury (16.7%), piece/material drop (16.7%), entering foreign object to eyes (16.7%), accidents from machines (8.3%), accidents of hand tools (8.3%), electric accidents (8.3%), crushing/jamming (16.7%), accidents resulting from touching harmful and dangerous items (8.3%). Five of these types of accidents (fall/injury, piece/material drop, accidents from machines, accidents of hand tools, crushing/jamming) can be caused by ergonomic inconvenience. Eight of the fifteen technicians who participated in the study experienced at least a work accident. These eight employees experienced a total of 12 work accidents in the past year. 67% of these job accidents can be caused by ergonomic inconveniences. As can be seen, the rate of job accidents that can be caused by ergonomic inconvenience is very high.

6.5.2 Method Usage

This section contains the usage of five ergonomic risk assessment methods chosen for IERAMCA methodology. In this section, there are Application of User Survey for Ergonomic Risks Method, Application of Cornell Musculoskeletal Discomfort Questionnaire Method, Application of Rapid Entire Body Assessment Method, Application of Computer Workstation Checklist Method, and Application of Copenhagen Psychosocial Questionnaire Method titles.

6.5.2.1 Application of User Survey for Ergonomic Risks Method

In this section, the answers given by the employees to the USGBC survey have been analyzed (Table 6.13, Table 6.14, Table 6.15 and Table 6.16). In Table 6.13, 15 survey questions are categorized in 3 separate categories. These categories are Workstation, Computer Workstation and Environmental. The question number of each survey question is given in the table. 46% of the questions in the questionnaire are related to workstation. 27% of the questions are related to computer workstation. and 27% of the questions are related to environmental.

Table 6.13 Classification of working environment

Classification of working environment	Question number	Questions about working environment
Workstation	Q1	Workstation allows me to work in a comfortable, supported neutral posture
Workstation	Q2	Workstation allows me to efficiently arrange my work items within easy reach
Workstation	Q3	Chair is comfortable, easy to adjust, and provides good back support
Computer Workstation	Q4	Keyboard is within easy reach and comfortably positioned for use with flat and straight hands
Computer Workstation	Q5	Mouse, trackball or touchpad within easy reach and comfortably positioned for use with my arm close by my side and my hand in flat and straight posture
Computer Workstation	Q6	Screen(s) within easy reach and comfortably positioned for viewing without neck bent or twisted
Computer Workstation	Q7	Document(s) within easy reach and comfortably positioned near screen for viewing without neck bent or twisted
Environmental	Q8	No visible glare on screen(s) or document(s)
Environmental	Q9	Sufficient light to comfortable read paper documents
Workstation	Q10	Worksurface is at a comfortable working height
Workstation	Q11	Adequate leg clearance under worksurface
Workstation	Q12	Feet are supported on floor or support surface
Workstation	Q13	I never experience frequent neck, back, shoulder, arm, hand or legs discomfort at my workstation
Environmental	Q14	Temperature usually is comfortable and indoor air quality is acceptable
Environmental	Q15	Background noise and speech privacy level usually is acceptable

In Table 6.14, there are number of satisfied employees and number of unsatisfied employees. In relation to the survey questions, 118 answers of the employees are unsatisfied, while 107 answers are satisfied according to the total answers. Most employees are suffering from background noise and speech privacy level, temperature, lack of foot support and uncomfortable chairs. Most employees are satisfied with lighting and working height.

Table 6.14 Number of satisfied and unsatisfied employees

Question number	Number of satisfied employees	Number of unsatisfied employees
Q1	5	10
Q2	7	8
Q3	3	12
Q4	11	4
Q5	7	8
Q6	13	2
Q7	8	7
Q8	7	8
Q9	14	1
Q10	12	3
Q11	9	6
Q12	3	12
Q13	5	10
Q14	2	13
Q15	1	14
Total Score	107	118

In Table 6.15, there are percentages of satisfied and unsatisfied employees. According to the percentage of dissatisfaction, the questions are sorted largest to smallest. 93% of the employees have stated that the noise in the working environment is not acceptable. 87% of the employees have stated that they are uncomfortable with the temperature level and ventilation in the laboratory environment. 80% of employees are unsatisfied with the lack of foot support and non-adjustable chairs. 67% of employees are unsatisfied because workstations do not support neutral position. 67% of employees have stated that they experienced musculoskeletal system discomfort in workstations. 53% of the employees have stated that workstation does not allow me to efficiently arrange my work items within easy reach and there is visible glare on screens. 53% of employees are not satisfied with the position of the mouse, trackball or touchpad. 47% of employees are not satisfied with the position of the documents. 40% of employees have stated that there is not adequate leg clearance under worksurface. 27% of employees are uncomfortable with their keyboard position. 20% of employees are uncomfortable from working height. 13% of employees are

uncomfortable with display positions, and 7% of employees are uncomfortable with lighting.

Table 6.15 Percentages of satisfied and unsatisfied employees

Questions about working environment	percentage of satisfied employees	percentage of unsatisfied employees
Q15	7%	93%
Q14	13%	87%
Q3	20%	80%
Q12	20%	80%
Q1	33%	67%
Q13	33%	67%
Q2	47%	53%
Q5	47%	53%
Q8	47%	53%
Q7	53%	47%
Q11	60%	40%
Q4	73%	27%
Q10	80%	20%
Q6	87%	13%
Q9	93%	7%

In Table 6.16, there are the percentage satisfied by total score and the percentage unsatisfied by total score. According to the total score, some questions with the highest percentage are explained. 12% of the total score reflects dissatisfaction with noise. 11% of the total score reflects dissatisfaction with the temperature, 10% of the total score reflects dissatisfaction with the chair and foot support.

Table 6.16 The percentage of satisfied and unsatisfied employees by total score

Questions about working environment	The percentage satisfied by total score	The percentage unsatisfied by total score
Workstation allows me to work in a comfortable, supported neutral posture	5%	8%
Workstation allows me to efficiently arrange my work items within easy reach	7%	7%
Chair is comfortable, easy to adjust, and provides good back support	3%	10%
Keyboard is within easy reach and comfortably positioned for use with flat and straight hands	10%	3%
Mouse, trackball or touchpad within easy reach and comfortably positioned for use with my arm close by my side and my hand in flat and straight posture	7%	7%
Screen(s) within easy reach and comfortably positioned for viewing without neck bent or twisted	12%	2%
Document(s) within easy reach and comfortably positioned near screen for viewing without neck bent or twisted	7%	6%
No visible glare on screen(s) or document(s)	7%	7%
Sufficient light to comfortable read paper documents	13%	1%
Worksurface is at a comfortable working height	11%	3%
Adequate leg clearance under worksurface	8%	5%
Feet are supported on floor or support surface	3%	10%
I never experience frequent neck, back, shoulder, arm, hand or legs discomfort at my workstation	5%	8%
Temperature usually is comfortable and indoor air quality is acceptable	2%	11%
Background noise and speech privacy level usually is acceptable	1%	12%

This section describes the application of the USGBC method. Environmental and physical risks in the work environment have been evaluated. Physical risks have been found to be very high. Therefore, a subjective method that analyzes physical risks in more detail should be used. The method chosen for this purpose is the CMDQ method.

6.5.2.2 Application of Cornell Musculoskeletal Discomfort Questionnaire Method

In this section, the available musculoskeletal disorders of the employees have been assessed by subjective assessment method. It examines the frequency, discomfort and interference of musculoskeletal complaints relative to 20 body parts. These 20 body parts are neck, right/left shoulder, upper back, right/left upper arm, lower back, right/left forearm, right/left wrist, hip/buttocks, right/left thigh, right/left knee, right/left lower leg, right/left foot. In addition, relations between some socio-demographic characteristics of employees and musculoskeletal system disorders have been investigated with this questionnaire. Percentage of employees who suffer from musculoskeletal disorders in the last week according to 20 body parts is summarized in Table 6.17. Additionally, discomfort and interference percentages of musculoskeletal disorders in 20 body parts are summarized in the table.

Table 6.17 CMDQ results

Body Parts	Frequency number(percentage)				
	Never	1-2 times/week	3-4 times/week	Every day	Several times every day
Neck	4(26.7)	5(33.3)	3(20)	2(13.3)	1(6.7)
Right shoulder	6(40)	2(13.3)	4(26.7)	0	3(20)
Left shoulder	8(53.3)	4(26.7)	1(6.7)	0	2(13.3)
Upper back	3(20)	4(26.7)	7(46.7)	1(6.7)	0
Right upper arm	9(60)	3(20)	2(13.3)	0	0
Left upper arm	11(73.3)	3(20)	1(6.7)	0	0
Lower back	3(20)	3(20)	6(40)	0	3(20)
Right forearm	11(73.3)	3(20)	1(6.7)	0	0
Left forearm	13(86.7)	0	0	0	2
Right wrist	9(60)	2(13.3)	3(20)	0	1(6.7)
Left wrist	11(73.3)	2(13.3)	0	0	2(13.3)
Hip	9(60)	3(20)	2(13.3)	0	1(6.7)
Right thigh	8(53.3)	4(26.7)	2(13.3)	0	1(6.7)
Left thigh	13(86.7)	2(13.3)	0	0	0
Right knee	5(33.3)	7(46.7)	3(20)	0	0
Left knee	12(80)	2(13.3)	2(13.3)	0	0
Right lower leg	12(80)	0	4(26.7)	0	0
Left lower leg	14(93.3)	0	2(13.3)	0	0
Right foot	7(46.7)	2(13.3)	5(33.3)	0	1(6.7)
Left foot	9(60)	0	3(20)	0	3(20)

Table 6.17 continues

Body Parts	Discomfort		
	Slightly uncomfortable n (%)	Moderately uncomfortable n (%)	Very uncomfortable n (%)
Neck	4(26.7)	6(40)	1(6.7)
Right shoulder	2(13.3)	6(40)	1(6.7)
Left shoulder	3(20)	3(20)	1(6.7)
Upper back	3(20)	7(46.7)	2(13.3)
Right upper arm	3(20)	2(13.3)	0
Left upper arm	1(6.7)	1(6.7)	2(13.3)
Lower back	2(13.3)	8(53.3)	2(13.3)
Right forearm	3(20)	1(6.7)	0
Left forearm	0	1(6.7)	1(6.7)
Right wrist	2(13.3)	4(26.7)	0
Left wrist	1(6.7)	3(20)	0
Hip	4(26.7)	1(6.7)	1(6.7)
Right thigh	3(20)	4(26.7)	0
Left thigh	1(6.7)	1(6.7)	0
Right knee	5(33.3)	5(33.3)	0
Left knee	3(20)	1(6.7)	0
Right lower leg	1(6.7)	3(20)	0
Left lower leg	0	2(13.3)	0
Right foot	4(26.7)	2(13.3)	2(13.3)
Left foot	1(6.7)	1(6.7)	4(26.7)

Table 6.17 continues

Body Parts	Interference		
	Not at all	Slightly interfered n (%)	Substantially interfered
Neck	3(20)	7(46.7)	1(6.7)
Right shoulder	3(20)	5(33.3)	1(6.7)
Left shoulder	3(20)	3(20)	1(6.7)
Upper back	2(13.3)	9(60)	1(6.7)
Right upper arm	2(13.3)	2(13.3)	1(6.7)
Left upper arm	2(13.3)	1(6.7)	1(6.7)
Lower back	0	11(73.3)	1(6.7)
Right forearm	2(13.3)	1(6.7)	1(6.7)
Left forearm	0	1(6.7)	1(6.7)
Right wrist	1(6.7)	5(33.3)	0
Left wrist	1(6.7)	3(20)	0
Hip	3(20)	3(20)	0
Right thigh	1(6.7)	6(40)	0
Left thigh	2(13.3)	0	0
Right knee	3(20)	6(40)	1(6.7)
Left knee	2(13.3)	2(13.3)	0
Right lower leg	0	4(26.7)	0
Left lower leg	0	2(13.3)	0
Right foot	2(13.3)	4(26.7)	2(13.3)
Left foot	1(6.7)	1(6.7)	4(26.7)

Table 6.18 lists frequency of discomforts (event column in table), prevalence and confidence intervals (significance level is 0.05) experienced in each body part. According to the table, in the last week 80% of employees experienced lower back discomfort, 80% of employees experienced upper back discomfort, 73.3% of employees experienced neck discomfort, 66.7% of employees experienced right knee discomfort, 60% of employees experienced right shoulder discomfort, 53.3% of employees experienced right foot discomfort, 46.7% of employees experienced left shoulder discomfort, 46.7% of employees experienced right thigh discomfort, 40% of employees experienced hip discomfort, 40% of employees experienced left foot discomfort, 40% of employees experienced right wrist discomfort, 33.3% of employees experienced right upper arm discomfort, 26.7% of employees experienced left upper arm discomfort, 26.7% of employees experienced right forearm discomfort, 26.7% of employees experienced left wrist discomfort, 20% of employees experienced right lower leg discomfort, , 20% of employees experienced left knee discomfort, , 13.3% of employees experienced left forearm discomfort, 13.3% of employees experienced left thigh discomfort, , 6.7% of employees experienced left lower leg discomfort.

Table 6.18 Frequency of discomforts, prevalence and confidence intervals

Body Parts	Event	Prevalance (%)	95% Confidence Interval for prevalence (lower limit, upper limit)
Lower back	12	80%	(0.597576, 1.000000)
Upper back	12	80%	(0.597576, 1.000000)
Neck	11	73.30%	(0.509545, 0.957122)
Right knee	10	66.70%	(0.428107, 0.905226)
Right shoulder	9	60%	(0.352082, 0.847918)
Right foot	8	53.30%	(0.280866, 0.785801)
Left shoulder	7	46.70%	(0.214199, 0.719134)
Right thigh	7	46.70%	(0.214199, 0.719134)
Hip	6	40%	(0.152082, 0.647918)
Left foot	6	40%	(0.152082, 0.647918)
Right wrist	6	40%	(0.152082, 0.647918)
Right upper arm	5	33.30%	(0.094774, 0.571893)
Left upper arm	4	26.70%	(0.042878, 0.490455)
Right forearm	4	26.70%	(0.042878, 0.490455)
Left wrist	4	26.70%	(0.042878, 0.490455)
Right lower leg	3	20%	(0.000000, 0.402424)
Left knee	3	20%	(0.000000, 0.402424)
Left forearm	2	13.30%	(0.000000, 0.305361)
Left thigh	2	13.30%	(0.000000, 0.305361)
Left lower leg	1	6.70%	(0.000000, 0.192900)

In Figure 6.44, musculoskeletal discomfort prevalence is shown. The prevalence of each body parts has been identified. The sequence of the body parts with the lowest prevalence from the highest prevalence is as follows: lower back, upper back, neck, right knee, right shoulder, right foot, left shoulder, right thigh, hip, left foot, right wrist, right upper arm, left upper arm, right forearm, left wrist, right lower leg, left knee, left forearm, left thigh, left lower leg.

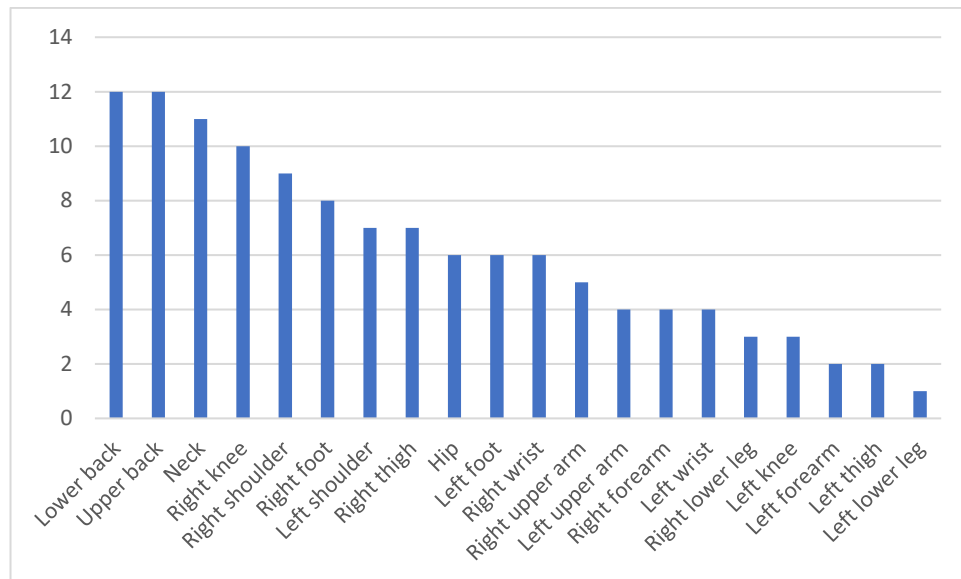


Figure 6.44 Musculoskeletal discomfort prevalence

Table 6.19 summarizes the Cornell Discomfort Score of each body part from the highest to the lowest. The scores of each body part according to the three areas of the Cornell musculoskeletal discomfort form (frequency, discomfort, interference) are explained in detail. Table 6.19 also shows the percentage of Cornell Discomfort Score scored by each body part in the total score.

Table 6.19 Cornell Discomfort Score

Body Parts	Frequency	Discomfort	Interference	Cornell discomfort score	Percentage
Lower back	55.5	21	25	29137.5	0.260338
Upper back	35.5	23	23	18779.5	0.167791
Neck	38	19	20	14440	0.129018
Right shoulder	47	17	16	12784	0.114222
Left foot	40.5	15	15	9112.5	0.081418
Right foot	30.5	14	16	6832	0.061043
Right knee	21	15	18	5670	0.05066
Left shoulder	29.5	12	11	3894	0.034792
Right thigh	23	11	13	3289	0.029387
Right wrist	23.5	10	11	2585	0.023096
Hip	21.5	6	9	1161	0.010373
Left wrist	23	7	7	1127	0.01007
Right lower leg	14	7	8	784	0.007005
Right upper arm	11.5	7	9	724.5	0.006473
Left forearm	20	5	5	500	0.004467
Left upper arm	8	7	7	392	0.003502
Left knee	10	5	6	300	0.00268
Right forearm	8	5	7	280	0.002502
Left lower leg	7	4	4	112	0.001001
Left thigh	3	3	2	18	0.000161

Figure 6.45 indicates that the Cornell Discomfort Score of each body part from the highest to the lowest. The body parts' score according to the Cornell discomfort score are as follows respectively: lower back, upper back, neck, right shoulder, left foot, right foot, right knee, left shoulder, right thigh, right wrist, hip, left wrist, right lower leg, right upper arm, left forearm, left upper arm, left knee, right forearm, left lower leg and left thigh.

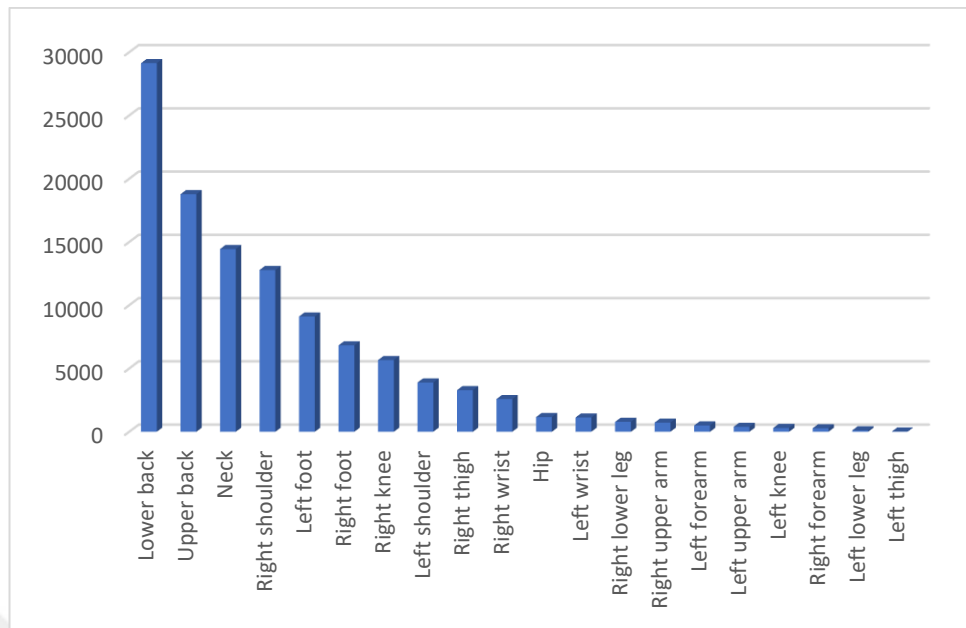


Figure 6.45 Cornell discomfort score

The scores that these each body parts received from the frequency section of the questionnaire were examined. According to the questionnaire, the incidence and the scores of the discomfort are: Never = 0, 1-2 times/week = 1.5, 3-4 times/week= 3.5, Every day = 5, Several times every day = 10. The frequency score of each body part has been calculated according to the incidence on this scale and the difference between these scores has been examined between male and female. Table 6.20 shows whether there is a difference in female and male frequency scores.

Table 6.20 Difference in female and male frequency score

Body Parts	<i>p</i> value
Lower back	0.021
Upper back	0.021
Neck	0.121
Right knee	0.009
Right shoulder	0.397
Right foot	0.663
Left shoulder	0.341
Right thigh	0.099
Hip	0.358
Left foot	0.114
Right wrist	0.168
Right upper arm	0.006
Left upper arm	0.017
Right forearm	0.179
Left wrist	0.655
Right lower leg	0.453
Left knee	0.407
Left forearm	0.118
Left thigh	0.117
Left lower leg	0.285

It has been investigated whether there is a significant difference between the average of frequency scores of lower back, upper back, neck, right knee, right shoulder, right foot, left shoulder, right thigh, hip, left foot, right wrist, right upper arm, left upper arm, right forearm, left wrist, right lower leg, left knee, left forearm, left thigh, left lower leg of females and males. The Mann Whitney U test has been used for this purpose. Analyzes have been performed using IBM SPSS 25 software. The significance level in the analyzes has been accepted as 0.05. According to the analysis results, body parts where there is a significant difference between the frequency scores between males and females: lower back ($p=0.021<0.05$), upper back ($p=0.021<0.05$), right knee ($p=0.009<0.05$), right upper arm ($p=0.006<0.05$) and left upper arm ($p=0.017<0.05$). The frequency score of musculoskeletal discomfort in the lower back, upper back, right knee, right upper arm and left upper arm differs according to the gender of the employees.

According to the analysis results, body parts where there is no significant difference between the frequency scores between males and females: neck ($p=0.121>0.05$), right shoulder ($p=0.397>0.05$), right foot ($p=0.663>0.05$), left shoulder ($p=0.341$), right thigh ($p=0.099>0.05$), hip ($p=0.358>0.05$), left foot ($p=0.114>0.05$), right wrist ($p=0.168>0.05$), right forearm ($p=0.179>0.05$), left wrist ($p=0.655>0.05$), right lower leg ($p=0.453>0.05$), left knee ($p=0.407>0.05$), left forearm ($p=0.118>0.05$), left thigh ($p=0.117>0.05$), left lower leg ($p=0.285>0.05$). The frequency score of musculoskeletal discomfort in the neck, right shoulder, right foot, left shoulder, right thigh, hip, left foot, right wrist, right forearm, left wrist, right lower leg, left knee, left forearm, left thigh and left lower leg does not differ according to the gender of the employees.

Table 6.21 indicates the total number of discomfort that all employees have according to body parts. An employee can have discomfort at least in zero body part and number of discomfort is not be more than twenty. The number of discomforts in the 20 body parts is expressed in a four range as shown on the Table 6.21. The table lists the number of people in that range. According to the information obtained with the self-reports of the employees, the total number of musculoskeletal discomfort the employees have has been determined. It has researched whether the mean number of total musculoskeletal discomfort varied according to male/female groups, single/married groups, work experience in years, weight, height, age groups and BMI range groups. The Mann Whitney U Test has been used to find the difference between the factors that could be separated into two separate categorizations. Kendall Tau Correlation has been used to determine the relationship between factors non-categorizable in two and number of discomfort.

Table 6.21 Number of discomforts experienced by employees

Number of Discomfort Experienced by Employees (ND) Scale		Number of ND<6	Number of 6≤ ND≤ 10	Number of 11 ≤ND ≤15	Number of ND >15	Total (ND)
Gender	Male	5	1	2	0	8
	Female	1	2	2	2	7
p^*	0.072					
Marital Status	Married	5	1	3	1	10
	Single	1	2	1	1	5
p^*	0.371					
Work Experience in Years	5-9 years	1	0	0	1	2
	10-14 years	5	2	3	0	10
	15-19 years	0	1	0	1	2
	>20 years	0	0	1	0	1
p^{**}	0.589					
Weight (kg)	50-59 kg	0	0	1	1	2
	60-69 kg	0	2	1	0	3
	70-79 kg	2	0	2	1	5
	80-89 kg	3	1	0	0	4
	>90 kg	1	0	0	0	1
p^{**}	0.034					
Height (cm)	150-159 cm	0	0	1	1	2
	160-169 cm	0	1	1	1	3
	170-179 cm	5	2	2	0	9
	>180 cm	1	0	0	0	1
p^{**}	0.023					
Age Groups (years)	30-34 years	1	1	1	0	3
	35-39 years	3	2	2	2	9
	40-44 years	2	0	0	0	2
	>45 years	0	0	1	0	1
p^{**}	0.531					
BMI Range	18 – 24.99 (normal)	1	2	4	1	8
	25 – 29.99 (overweight)	5	1	0	1	7
p^{**}	0.048					

*Mann Whitney U Test, **Kendall's Tau

According to the Mann Whitney U test (in Table 6.21), there is no meaningful difference in the number of musculoskeletal disorders that males and females have ($p=0.072>0.05$). At the same time there is no meaningful difference in the number of

musculoskeletal disorders that single employees and married employees have ($p=0.371>0.05$). No statistically significant relationship is found between the number of musculoskeletal disorders seen in employees and work experience in years factor ($p=0.589>0.05$) and the age factor ($p=0.531>0.05$). On the other hand, a statistically significant relationship is found between the weight factor ($p=0.034<0.05$), height factor ($p=0.023<0.05$), BMI range ($p=0.048<0.05$), factor and the number of musculoskeletal disorders the employees have.

6.5.2.3 Application of Rapid Entire Body Assessment Method

In this section, REBA analysis has been performed for all core, main and sub-tasks in the workplace. A sample of the application of the REBA analysis for a sub-task. The sample application of the REBA analysis is shown in the tables below. In this section, the sub-task that is examined as an example belongs to a main task. This main task is “Plasma shocking process”. Plasma shocking process consists of 5 sub-tasks. The sub-task in this posture analysis is “Plasmas are inserted into the shocking device”.

In Table 6.22, the trunk is analyzed. The trunk is flexed between 20° and 60° and side bending (3+1). So, the trunk score is 4.

Table 6.22 Trunk score

Trunk		
Posture	Score	Adjust of score
Natural posture	1	If the trunk is twisted +1 If the trunk is side bending +1
0°-20° Flexion	2	
Extension	2	
20°-60° Flexion	3	
>60° Flexion	4	

In Table 6.23, the neck is analyzed. The neck is flexed more than 20° and side bending (2+1). So, the neck score is 3.

Table 6.23 Neck score

Neck		
Posture	Score	Adjust of score
0-20° Flexion	1	If the neck is twisted +1 If the neck is side bending +1
>20° Flexion	2	
Extension	2	

In Table 6.24, the legs are analyzed. The legs are in bilateral posture and flexed more than 60° (1+2). So, the leg score is 3.

Table 6.24 Leg score

Legs		
Posture	Score	Adjust of score
Bilateral	1	30°-60° Flexion +1
Unilateral	2	>60° Flexion +2

In Table 6.25, is used to find the subtotal. It is Table A. According to trunk, neck and legs score, the posture score A is 8.

Table 6.25 Posture score A

Table A	Neck Score												
		1				2				3			
	Legs Score												
		1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	5	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

In Table 6.26, force/load score is 0. The force/load score is added to posture score A (8+0) and score A is obtained. So, score A is 8.

Table 6.26 Force/load score

Force/Load	Score	Adjust of score
<5 kg	0	If shock or rapid build up force +1
5-10 kg	1	
>10 kg	2	

In Table 6.27, the upper arm is analyzed. Upper arm is flexed between 45° and 90° (3), abducted (+1). So, the upper arm score is 4.

Table 6.27 Upper arm score

Upper Arm		
Posture	Score	Adjust of score
0-20° Flexion 0-20° Extension	1	If shoulder is raised +1 If upper arm is abducted +1 If arm is supported or person is leaning -1
> 20° Extension	2	
20-45 Flexion	2	
45-90 Flexion	3	
>90 Flexion	4	

In Table 6.28, the lower arm is analyzed. Lower arm is flexed more than 100° (2). So, the lower arm score is 2.

Table 6.28 Lower arm score

Lower Arm	
Posture	Score
60° - 100° Flexion	1
< 60° Flexion	2
> 100° Flexion	2

In Table 6.29, the wrist is analyzed. Wrist is more than 15° flexion/extension (2) with twist (+1). So, the wrist score is 3.

Table 6.29 Wrist score

Wrist		
Posture	Score	Adjust of score
0° - 15° Flexion or Extension	1	If wrist is bent from midline or twisted +1
> 15 ° Flexion or Extension	2	

In Table 6.30, is used to find the subtotal. It is Table B. According to upper arm, lower arm and wrist score, the posture score B is 7.

Table 6.30 Posture score B

Table B	Lower Arm Score						
		1			2		
	Wrist Score						
		1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

In Table 6.31, there are poor coupling. So, the coupling score is 2. Coupling score is added to the posture score B (7+2). The score B is 9.

Table 6.31 Coupling score

Coupling	
Status	Score
Well-fitting handle and mid rang power grip, good	0
Acceptable but not ideal hand hold or coupling acceptable with another body part, fair	1
Hand hold not acceptable but possible, poor	2
No handles, awkward, unsafe with any body part, unacceptable	3

In Table 6.32, score C is obtained from Table C. According to score A and score B, score C is obtained (10).

Table 6.32 Score C

Score A (Posture score A+ Force/Load Score)	Table C											
	Score B (Posture score B+ Coupling score)											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	11	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

In Table 6.33, the activity table is shown. There are repeated small range actions. So, the activity score is 1. This score is added to score C (10+1).

Table 6.33 Activity score

Activity	
Status	Score
If one or more body parts are held for longer than 1 minute (static)	+1
Repeated small range actions (more than 4 times per minute)	+1
Action causes rapid large range changes in postures or unstable base	+1

The REBA score is 11. The level of risk is very high according to Table 6.34.

Table 6.34 REBA score

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

Calculation of the weights of the processes is determined below. Processes in the laboratory consists of 3 groups. These 3 processes are blood group identification process, cross-match process and product preparation process. These 3 processes consist of 22 main tasks. 22 main tasks consist of 201 sub-tasks.

The following steps are applied to determine the risk level of laboratory tasks:

- The REBA scores of all sub-tasks are determined.
- The REBA scores of the main tasks are determined by taking the averages of The REBA scores of the sub-tasks for each main task.
- The average REBA scores of the main task are calculated for the processes to which they belong and the average score of each process is determined.
- But each process has different weights according to the frequency of implementation of them.
- These weights should be determined by group decision.
- So, 3 laboratory technicians and a supervisor have been consulted to determine the weights of these 3 processes.
- The weights of the processes according to the average of the notifications received are determined as and they are shown in Figure 6.46: blood group identification process (32.5%), cross-match process (32.5%) and product preparation process (35%) (Figure 6.46).

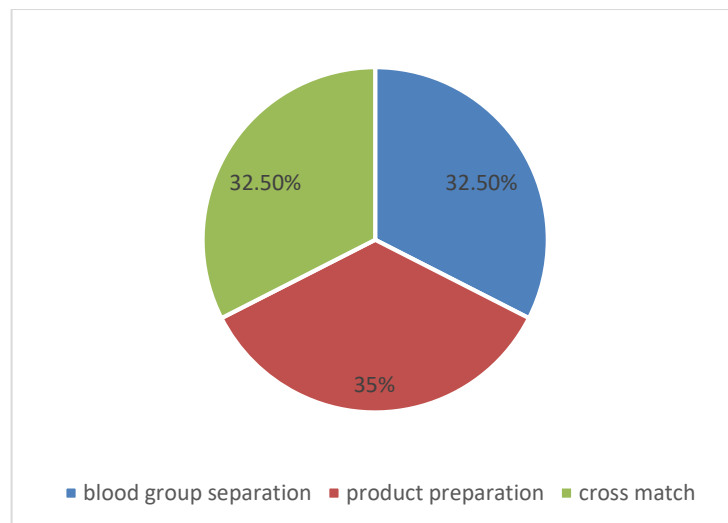


Figure 6.46 The weights of the processes

In Table 6.35, REBA scores of the 22 main tasks in the laboratory have been calculated. The average of the REBA scores of the sub-tasks of each main task has been used when performing this calculation. Then, a general REBA score has been

calculated. In the general REBA score, the above-mentioned core tasks weights have been used. Each main task is weighted by the weight of the process it belongs to. According to the table, the weighted general REBA score is 6.1322. This score is in medium risk group.

Table 6.35 The score of the general REBA application

Main Tasks	Average	Scoring
1.Taking Samples from Whole Blood Bag	6.81818182	medium
2.Centrifugation of Whole Blood Bags	6.83333333	medium
3.Erythrocyte and Plasma Separation	5.36363636	medium
4.Removal of Filtered Erythrocytes	7.4	high
5.Platelet Separation	6.13333333	medium
6.Labeling of Products	8.2	high
7.Plasma shocking process	9.6	high
8.Thrombocyte pooling	8.33333333	high
9. Infection Test	4.81818182	medium
10. Witness sample separation	6.44444444	medium
11. Loading distile water to the autoanalyzer	8	high
12.Placement of the solutions required for the operation of the autoanalyzer	6.58333333	medium
13. Tube Centrifuge in the Microcentrifuge	5	medium
14. Erythrocyte reservation	5.5625	medium
15.Blood Group Identification Process	5.08333333	medium
16. Discharge of waste water from cross match and blood group machine	8.66666667	high
17. Gel card centrifuge	3.5	low
18. Manual filling of gel cards for blood group and cross match machine operations	4.26666667	medium
19. Preparing cross and blood group machines for operating	7	medium
20. Plasma and thrombocyte reservation	9	high
21. Removal of reservations for products that expire at the end of the reservation	9	high
22. Blood irradiation technique	6	medium
Average according to the weights	6.1322	medium

In Figure 6.47, count of main tasks according to the risk group. A main task is in low risk group. 13 main tasks are in medium risk group. 8 main tasks are in high risk group. There is no main task in negligible and very high risk groups.

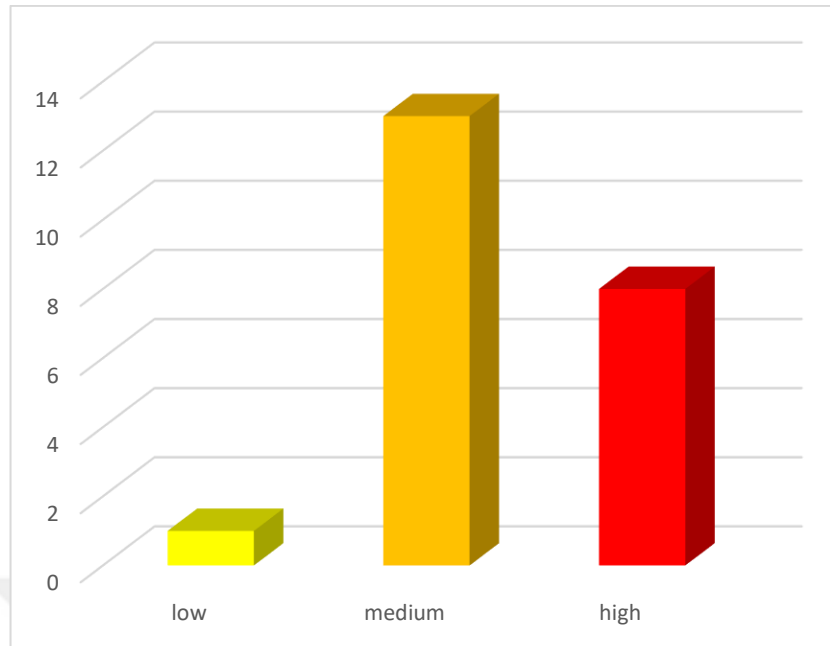


Figure 6.47 Count of main tasks

Figure 6.48 presents percentage of main tasks according to the risk range. 5% of main tasks are in low risk group. 59% of main tasks are in medium risk group. 36% of main tasks are in high risk group.

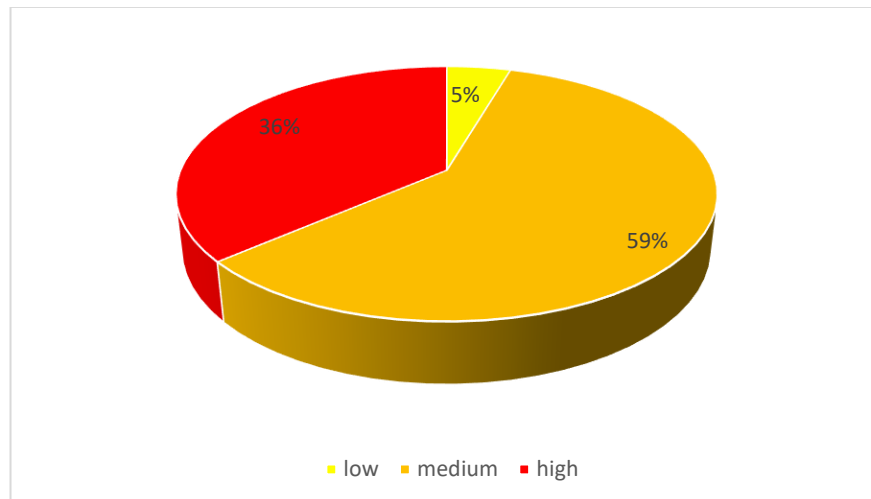


Figure 6.48 Percentage of main tasks

In Table 6.36, there are risk distributions of main tasks. REBA analysis of the sub-tasks of the main tasks has been performed. The distribution of risk levels of sub-tasks is given in the table according to main tasks. For example, according to the table, “Taking Samples from Whole Blood Bag” main task has 11 sub-tasks. 6 of these sub-tasks are medium risk group and 5 of these sub-tasks are high risk group.

Table 6.36 Risk distributions of main tasks

Main Tasks	negligible risk	low risk	medium risk	high risk	very high risk
1.Taking Samples from Whole Blood Bag	0	0	6	5	0
2.Centrifugation of Whole Blood Bags	3	0	3	6	0
3.Erythrocyte and Plasma Separation	0	3	8	0	0
4.Removal of Filtered Erythrocytes	0	0	4	6	0
5.Platelet Separation	3	2	5	5	0
6.Labeling of Products	0	1	4	8	2
7.Plasma shocking process	0	1	0	0	4
8.Thrombocyte pooling	0	0	2	4	0
9. Infection Test	1	4	2	4	0
10. Witness sample separation	0	0	5	4	0
11. Loading distile water to the autoanalyzer	0	0	3	1	1
12.Placement of the solutions required for the operation of the autoanalyzer	0	1	7	4	0
13. Tube Centrifuge in the Microcentrifuge	1	1	0	2	0
14. Erythrocyte reservation	1	3	8	2	2
15.Blood Group Identification Process	1	3	5	3	0
16. Discharge of waste water from cross match and blood group machine	0	0	1	5	0
17. Gel card centrifuge	1	2	3	0	0
18. Manual filling of gel cards for blood group and cross match machine operations.	2	3	10	0	0
19. Preparing cross and blood group machines for operating.	0	0	4	2	0

Table 6.36 continues

20. Plasma and thrombocyte reservation	0	0	1	2	2
21. Removal of reservations for products that expire at the end of the reservation.	0	0	1	2	2
22. Blood irradiation technique	0	0	3	0	1
Total	13	24	85	65	14

In the appendices section, In Table 3, REBA scores all the sub-tasks are shown. In Table 6.37 and Table 6.38, count and percentages of the risk types are given. In Figure 6.49 and figure 6.50, the graphics of these tables are indicated. 13 sub-tasks are in the negligible risk group. 24 sub-tasks are in the low risk group. 85 sub-tasks are in the medium risk group. 65 sub-tasks are in the high risk group. 14 sub-tasks are in the very high risk group.

Table 6.37 Count of risk types

Scoring	total count
negligible risk	13
low risk	24
medium risk	85
high risk	65
very high risk	14
Total	201

Table 6.38 Percentage of risk types

Scoring	percentage
negligible risk	6%
low risk	12%
medium risk	42%
high risk	32%
very high risk	7%

6 percent of sub-tasks is in the negligible risk group. 12 percent of sub-tasks is in the low risk group. 42 percent of sub-tasks is in the medium risk group. 32 percent of

sub- tasks is in the high risk group. 7 percent of the sub-tasks is in the very high risk group.

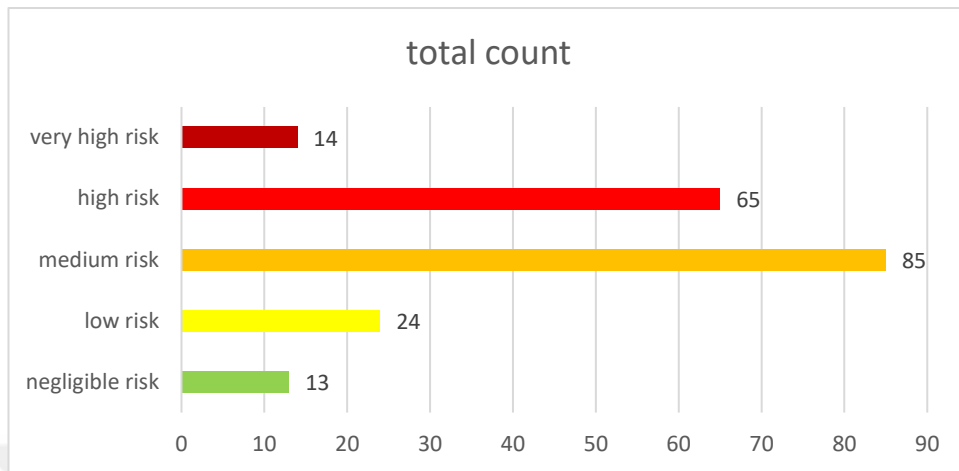


Figure 6.49 Total count of the risk types

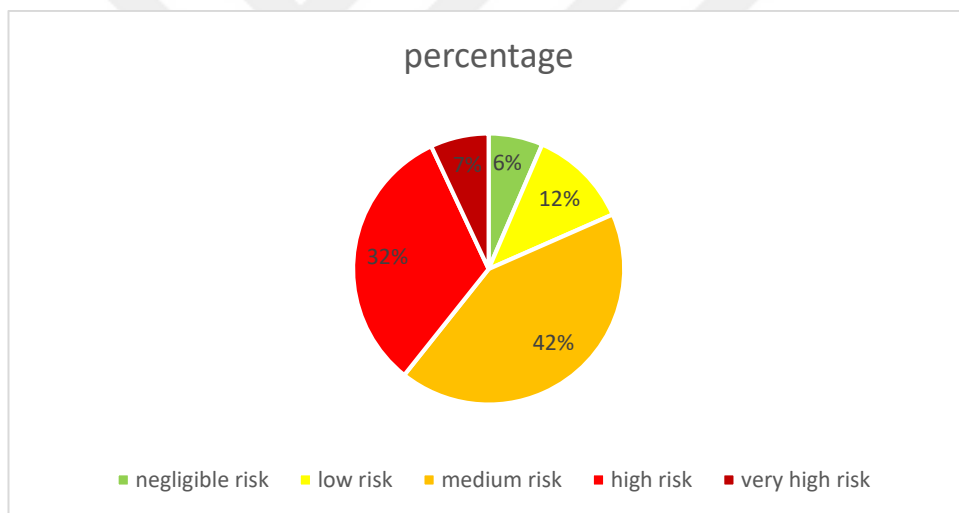


Figure 6.50 Percentage of the risk types in REBA

In addition, computerized tasks with REBA have been also analyzed. There are 23 computerized sub-tasks available. Computer workstations are used in 10 main tasks. In Table 6.39, computer sub-tasks' REBA results are shown. Average REBA result for computerized tasks is 5.478. It is in medium risk group.

Table 6.39 Results of the computer tasks

Main task group they belong to	Main Task No	Risk scoring	Average REBA Result for computer-based tasks	Scoring
6.Labeling of Products	6	low	5.478261	MEDIUM RISK
	7	high		
	8	medium		
	9	high		
9.Infection Test	5	medium		
	7	low		
	8	low		
	10	Low		
10.Witness sample separation	2	medium		
12.Placement of the solutions required for the operation of the autoanalyzer	12	Low		
14.Erythrocyte reservation	2	medium		
	10	medium		
	11	medium		
	14	medium		
15.Blood Group	7	medium		
	8	medium		
	11	medium		
19.Preparing cross and blood group machines for operating.	6	medium		
20.Plasma and thrombocyte reservation	1	high		
	3	high		
21.Removal of reservations for products that expire at the end of the reservation.	1	high		
	3	high		
22.Blood irradiation technique	4	medium		

In the analysis of computerized tasks, these tasks should be evaluated with a different evaluation method other than REBA. Therefore, these tasks have been also evaluated by the Computer Workstation Checklist Method in this study.

6.5.2.4 Application of Computer Workstation Checklist Method

This method does not evaluate works separately. Works are evaluated on the basis of computer workstations. Ergonomic conformity of computer workstations is evaluated. Questions about computerized workstations are available in this method. There are sub-tasks in each workstation. There are 6 computer workstations in the application laboratory. There are sub-works at each workstation. Each sub-task is also dependent on a main task. The sub-tasks in the computer workstations are given in the Table 6.41. In Table 6.40, colors used to indicate workstations are shown.

Table 6.40 Colors of the computer workstations

WS1	
WS2	
WS3	
WS4	
WS5	
WS6	

Table 6.41 The sub-tasks in the computer workstations

Main Task No	Sub-task No	Sub-task
6.Labeling of Products	6	The related pages are opened on the computer screen.
	7	Barcode on the bag is read via reader.
	8	The label output of the product is taken.
	9	The labels is read via reader again.
9.Infection Test	5	The label on the tube is read through the label reader.
	7	The device is run in the appropriate program.
	8	The operation of the device is followed.
	10	The results are checked from the computer.
10.Witness sample separation	2	The barcodes of the infection test samples from the autoanalyzer are read and appropriate labels are collected.
12.Placement of the solutions required for the operation of the autoanalyzer	12	It is checked on the screen that the device is working properly.

Table 6.41 continues

14.Erythrocyte reservation	2	The label on the tube is read to see what the doctor wants.
	10	The device is run in the appropriate program.
	11	The operation of the device is followed.
	14	If the cross match test results are acceptable, the reserve label is printed on the product.
15.Blood Group	7	The device is run in the appropriate program.
	8	The operation of the device is followed.
	11	The label of the result is printed for products.
19.Preparing cross and blood group machines for operating.	6	Things loaded in the machine is introduced to the computer.
20.Plasma and thrombocyte reservation	1	The desired products for the patients are checked from the computer screen.
	3	The product is booked from the system on behalf of the patient.
21.Removal of reservations for products that expire at the end of the reservation.	1	The list of products that need to be booked down is looked at from the screen.
	3	Barcode is read and removed from the system.
22.Blood irradiation technique	4	The irradiated product labels are adhered to the irradiated products.

The photos of the 6 computer workstations are shown below (Figure 6.51, Figure 6.52, Figure 6.53, Figure 6.54, Figure 6.55, Figure 6.56). The photos belong to computer workstation respectively; computer workstation-1, computer workstation-2, computer workstation-3, computer workstation-4, computer workstation-5 and computer workstation-6.

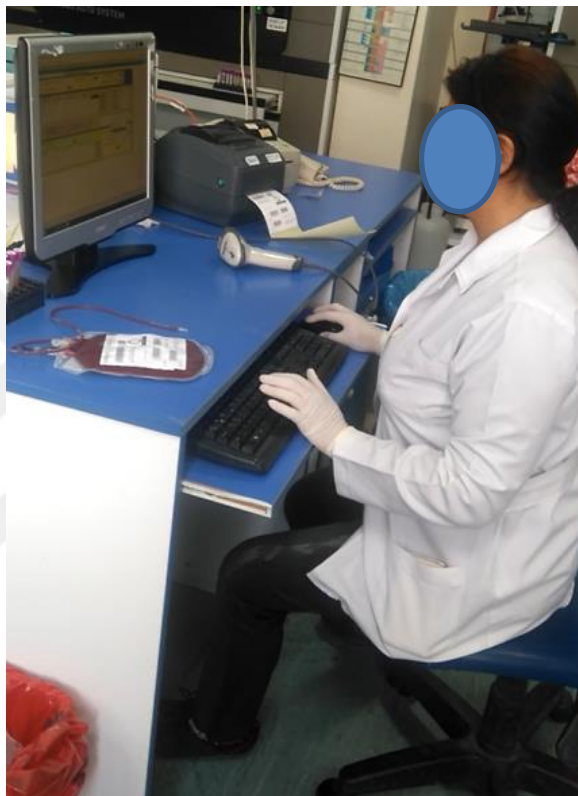


Figure 6.51 VDT Workstation-1 (Personal archive, 2018)

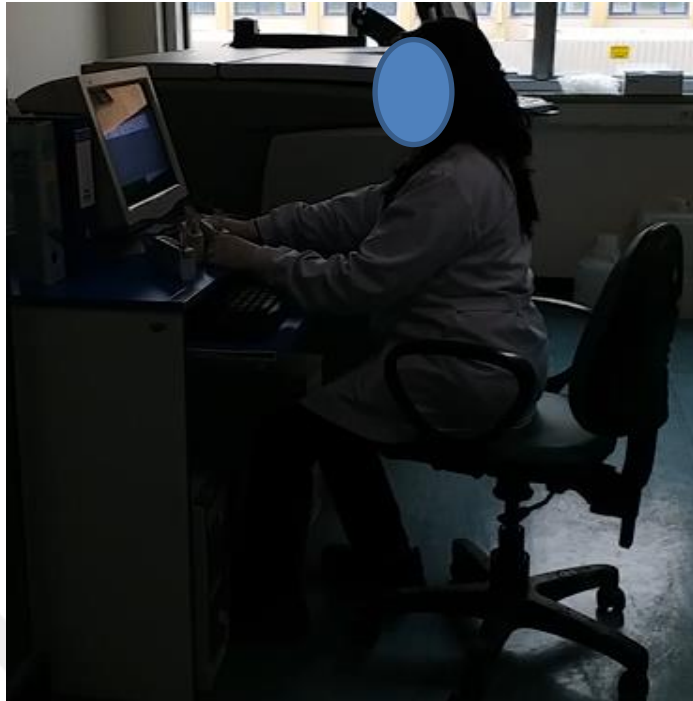


Figure 6.52 VDT Workstation-2 (Personal archive, 2018)

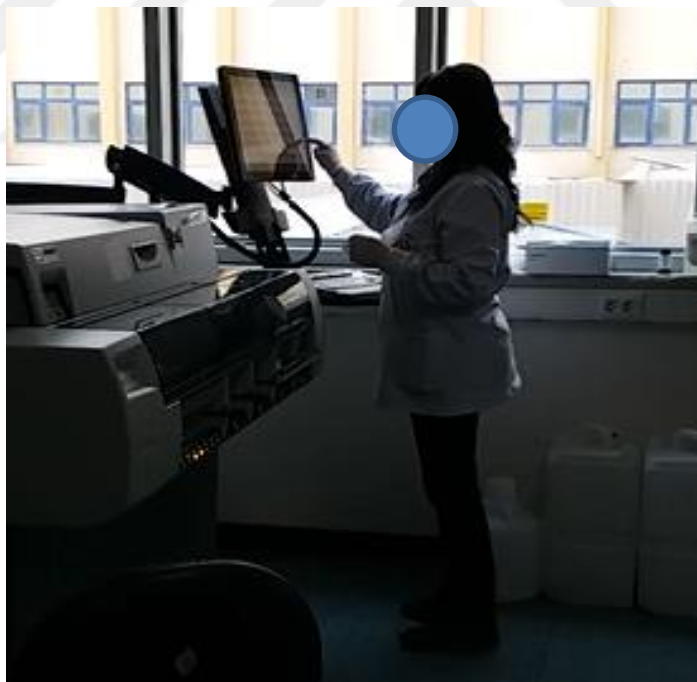


Figure 6.53 VDT Workstation-3 (Personal archive, 2018)

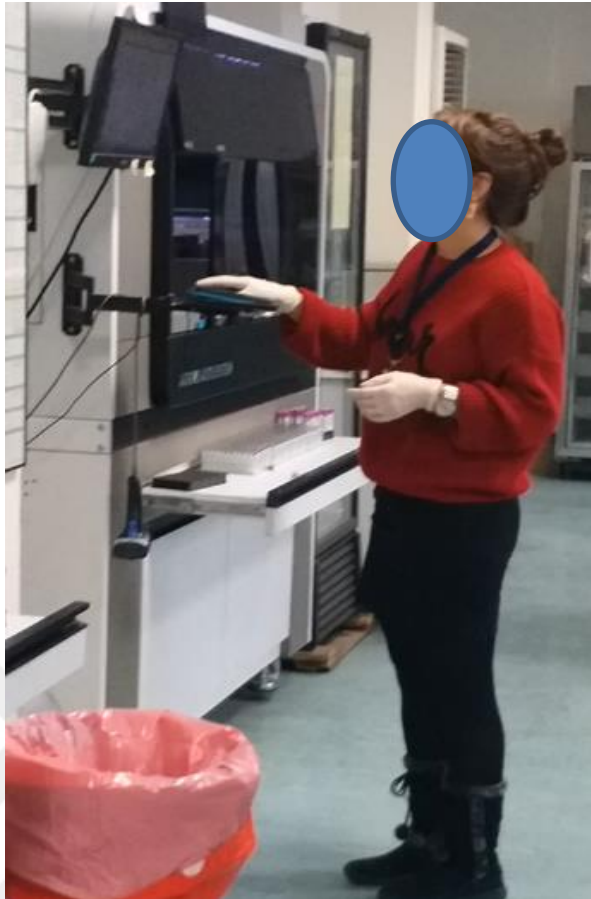


Figure 6.54 VDT Workstation-4 (Personal archive, 2018)

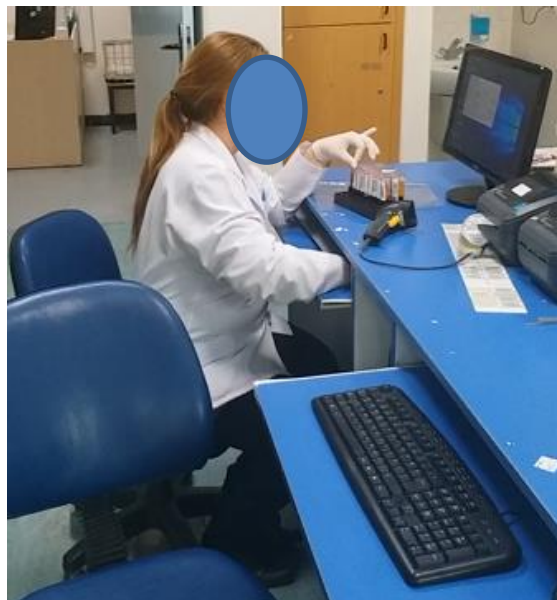


Figure 6.55 VDT Workstation-5 (Personal archive, 2018)



Figure 6.56 VDT Workstation-6 (Personal archive, 2018)

In Table 6.42, there are the VDT evaluation of 6 computer workstations. Computer workstations have been evaluated according to working conditions, seating, keyboard, monitor, work area, accessories. The abbreviations of “Y” and “N” in the table refer to “Yes” and “No” (answers to questions). The question lettering and the question numbers are as described in Table 6.5.

Table 6.42 VDT checklist analysis

	WS1		WS2		WS3		WS4		WS5		WS6		
WORKING CONDITIONS		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
A		1		1		1			1	1		1	
B		1		1		1		1		1		1	
C		1		1		1		1			1		1
D		1		1			1		1		1		1
E		1		1			1		1		1		1
F		1		1			1		1	1		1	
G		1		1		1		1		1		1	
H			1		1		1		1		1		1
I		1		1		1		1			1		1
		8	1	8	1	5	4	4	5	4	5	4	5
SEATING		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
1			1		1		1		1		1		1
2		1		1			1		1	1		1	
3		1		1			1		1	1		1	
4		1		1			1		1	1		1	
5			1		1		1		1		1		1
		3	2	3	2	0	5	0	5	3	2	3	2
KEYBOARD/ INPUT DEVICE		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
6			1		1		1		1		1	1	
7		1		1		1		1		1		1	
8		1		1		1		1		1		1	
9			1		1		1		1		1		1
		2	2	2	2	2	2	2	2	2	2	3	1
MONITOR		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
10			1	1			1		1		1		1
11		1		1		1		1		1		1	

Table 6.42 continues

12	1			1		1		1		1		1	
13	1			1		1		1		1		1	
14			1		1		1		1		1		1
	3		2	4	1	3	2	3	2	3	2	3	2
WORK AREA		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
15	1			1		1		1		1			1
16	1			1		1		1		1			1
	2		0	2	0	2	0	2	0	2	0	0	2
ACCESSORIES	Y		N	Y	N	Y	N	Y	N	Y	N	Y	N
17			1		1		1		1		1		1
18			1		1		1		1		1		1
19			1		1		1		1		1		1
20			1		1		1		1		1		1
21			1		1		1		1		1		1
	0		5	0	5	0	5	0	5	0	5	0	5
GENERAL	Y		N	Y	N	Y	N	Y	N	Y	N	Y	N
22			1		1	1			1		1		1
23			1		1		1		1		1		1

	0	2	0	2	1	1	0	2	0	2	0	2
Total Score	18	14	19	13	13	19	11	21	14	18	13	19
	56 %	44 %	59 %	41 %	41 %	59 %	34 %	66 %	44 %	56 %	41 %	59 %

General evaluation results are shown in Table 6.43. 104 of the questions on the checklist have “No” answer and 88 of the questions on the checklist have “Yes” answer.

Table 6.43 The score of answers

VDT Checklist	
The score of NO answers	104
The score of YES answers	88

“No” answer in the question refers to the unsuitability ergonomically. “No” answers received from each VDT section have been analyzed below:

- In the working conditions section, the percentages of no answer according to the workstations are as follows: 11% (WS1), 11% (WS2), 44% (WS3), 55% (WS4), 55% (WS5), 55% (WS6).
- In the seating section, the percentages of no answer according to the workstations are as follows: 40% (WS1), 40% (WS2), 100% (WS3), 100% (WS4), 40% (WS5), 40% (WS6).
- In the keyboard/input device section, the percentages of no answer according to the workstations are as follows: 50% (WS1), 50% (WS2), 50% (WS3), 50% (WS4), 50% (WS5), 25% (WS6).
- In the monitor section, the percentages of no answer according to the workstations are as follows: 40% (WS1), 20% (WS2), 40% (WS3), 40% (WS4), 40% (WS5), 40% (WS6).
- In the work area section, the percentages of no answer according to the workstations are as follows: 0% (WS1), 0% (WS2), 0% (WS3), 0% (WS4), 0% (WS5), 100% (WS6).
- In the accessories section, the percentages of no answer according to the workstations are as follows: 100% (WS1), 100% (WS2), 100% (WS3), 100% (WS4), 100% (WS5), 100% (WS6).
- In the general section, the percentages of no answer according to the workstations are as follows: 100% (WS1), 100% (WS2), 50% (WS3), 100% (WS4), 100% (WS5), 100% (WS6).

6.5.2.5 *Application of Copenhagen Psychosocial Questionnaire Method*

Abbreviations and evaluation scale of 20 psychosocial dimensions in the COPSOQ questionnaire have been given in Table 6.44. In scoring of the of the questionnaire used 1-2-3-4-5 scoring. All psychosocial dimensions are assessed as internal. Some of the dimensions are aimed at the maximization in scoring, while others are aimed at minimization. Therefore, some dimensions according to the purposes of the dimensions have been entered in reverse coding while being encoded in the SPSS program. The inverse coding of some dimensions is presumed, and according to this assumption, the reproduced COPSOQ evaluation scale is as follows in Table 6.44. All

evaluations and calculations made with COPSOQ in this study have been made according to the new assessment scale.

All total scores that a dimension can take when COPSOQ is evaluated have been calculated. The median value is calculated by sorting the scores that a dimension has from small to large. The dimension scores that are smaller than median values were defined as low risk. The dimension scores that are larger than median values are defined as high risk. If a dimension score is equal to the median value, it is defined as medium risk.



Table 6.44 COPSOQ assessment scale

	Low								Medium	High									
quantitative (Q)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
cognitive (C)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
emotional (E)			3	4	5	6	7	8	9	10	11	12	13	14	15				
hiding emotions (H)					2	3	4	5	6	7	8	9	10						
sensorial (S)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
influence at work (I)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
development possibilities (D)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
degree of freedom (DF)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
meaning of work (M)			3	4	5	6	7	8	9	10	11	12	13	14	15				
commitment to the workplace (CW)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
predictability (P)					2	3	4	5	6	7	8	9	10						
rol clarity (R)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
role conflicts (RC)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
quality of leaership (QL)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
social support (SS)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
feedback of work(F)					2	3	4	5	6	7	8	9	10						
social relations (SR)					2	3	4	5	6	7	8	9	10						
sense of community (SC)			3	4	5	6	7	8	9	10	11	12	13	14	15				
insecurity at work(IW)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
job satisfaction (J)			4	5	6	7	8	9	10	11	12	13	14	15	16				

In Table 6.45, percentage of psychosocial risk dimensions is shown. The risk level of each psychosocial risk dimensions has been determined. It has been determined how many people scored low, medium and high risk levels for psychosocial risk dimensions. There are also percentages of low, medium and high risk scores in each dimension in table.

Table 6.45 Percentage of psychosocial risk dimensions

Psychosocial Risk Dimensions	Person Number	Percent	Psychosocial Risk Dimensions	Person Number	Percent
Quantitative Demands			Predictability		
Low Risk Score	2	13%	Low Risk Score	6	40%
Medium Risk Score	4	27%	Medium Risk Score	1	7%
High Risk Score	9	60%	High Risk Score	8	53%
Cognitive Demands			Role Clarity		
Low Risk Score	0	0%	Low Risk Score	15	100%
Medium Risk Score	3	20%	Medium Risk Score	0	0%
High Risk Score	12	80%	High Risk Score	0	0%
Emotional Demands			Role Conflicts		
Low Risk Score	7	47%	Low Risk Score	7	47%
Medium Risk Score	3	20%	Medium Risk Score	2	13%
High Risk Score	5	33%	High Risk Score	6	40%
Demands for Hiding Emotions			Quality of Leadership		
Low Risk Score	8	53%	Low Risk Score	8	53%
Medium Risk Score	4	27%	Medium Risk Score	2	13%
High Risk Score	3	20%	High Risk Score	5	33%
Sensorial Demands			Social Support		
Low Risk Score	0	0%	Low Risk Score	9	60%
Medium Risk Score	0	0%	Medium Risk Score	0	0%
High Risk Score	15	100%	High Risk Score	6	40%
Influence at Work			Feedback at Work		
Low Risk Score	0	0%	Low Risk Score	6	40%
Medium Risk Score	0	0%	Medium Risk Score	4	27%
High Risk Score	15	100%	High Risk Score	5	33%

Table 6.45 continues

Possibilities for Development			Social Relations		
Low Risk Score	12	80%	Low Risk Score	14	93%
Medium Risk Score	1	7%	Medium Risk Score	0	0%
High Risk Score	2	13%	High Risk Score	1	7%
Degree of Freedom at Work			Sense of Community		
Low Risk Score	6	40%	Low Risk Score	11	73%
Medium Risk Score	3	20%	Medium Risk Score	2	13%
High Risk Score	6	40%	High Risk Score	2	13%
Meaning of Work			Insecurity at Work		
Low Risk Score	14	93%	Low Risk Score	9	60%
Medium Risk Score	1	7%	Medium Risk Score	1	7%
High Risk Score	0	0%	High Risk Score	5	33%
Commitment to the Workplace			Job Satisfaction		
Low Risk Score	12	80%	Low Risk Score	9	60%
Medium Risk Score	1	7%	Medium Risk Score	2	13%
High Risk Score	2	13%	High Risk Score	4	27%

In Table 6.46, there are the risk level of each psychosocial risk dimensions. The risk level of each dimension has been determined according to the dimension averages.

Table 6.46 Risk level of each psychosocial risk dimensions

Psychosocial Risk Dimensions	Risk Level	Psychosocial Risk Dimensions	Risk Level
Quantitative Demands	High	Predictability	Medium
Cognitive Demands	High	Role Clarity	Low
Emotional Demands	Low	Role Conflicts	Low
Demands for Hiding Emotions	Low	Quality of Leadership	Low
Sensorial Demands	High	Social Support	Low
Influence at Work	High	Feedback at Work	Medium
Possibilities for Development	Low	Social Relations	Low
Degree of Freedom at Work	Low	Sense of Community	Low
Meaning of Work	Low	Insecurity at Work	Low
Commitment to the Workplace	Low	Job Satisfaction	Low

In Figure 6.57, percentage distribution of risks by dimensions is shown. 70% of the dimensions are at low risk level. 10% of the dimensions are at medium risk level. 20% of the dimensions are at high risk level.

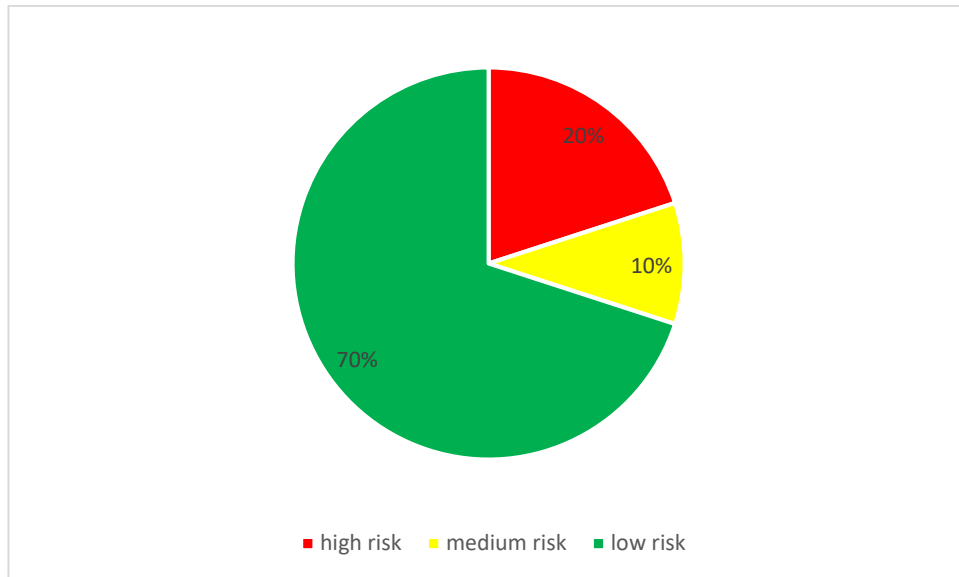


Figure 6.57 Percentage distribution of risks by dimensions

In Table 6.47, The internal consistency of the COPSOQ scale has been assessed by the Cronbach's alpha coefficients obtained for each dimension. Cronbach's alpha coefficients, confidence interval of the scores according to the dimensions, Corrected Item-Total Correlation and Cronbach's alpha coefficients if item deleted are shown for each dimension of the COPSOQ scale. The Cronbach's alpha coefficients range from 0 to 1. The variation range of Cronbach's alpha coefficients is as follows:

- 0.80 - 1.00 High reliability
- 0.60 - 0.79 Reliable
- 0.40 - 0.59 Low reliability
- 0- 0.39 Unreliable

When the fourth question of the quantitative demands dimension, third question of the emotional demands dimension, first question of the possibilities for development demands dimension, first question of the development opportunity dimension, third question of the meaning of work dimension, second question of the role clearance dimension, first question of the role conflict dimension, second question of the social support dimension are deleted, when Cronbach's alpha coefficients are examined, it is seen that the coefficients of each one is higher than Cronbach's alpha value in table .

Table 6.47 Cronbach's alpha coefficient

Dimensions and Question Numbers	Confidence Interval	Cronbach's Alpha	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
quantitative demands	12.625±0.989747955	0.4605475		
1	3.75±0.238303304		.628	.205
2	3.0625±0.305719394		.245	.413
3	2.75±0.456316086		.614	-.078 ^a
4	3.0625±0.531751098		-.064	.789
cognitive demands	14.6875±1.078415704	0.66734486		
1	4.625±0.329915985		.334	.668
2	4.0625±0.455017887		.575	.504
3	3±0.275168953		.363	.656
4	3±0.435080317		.564	.513
emotional demands	8.25±1.326816642	0.74395161		
1	2.8125±0.590772747		.692	.501
2	2.75±0.567275329		.873	.243
3	2.6875±0.465302075		.244	.957
hiding feelings	4.5625±1.150600313	0.7792672		
1	1.9375±0.598729641		.642	-
2	2.625±0.670503799		.642	-
sensorial demands	19.125±0.724771203	0.705		
1	4.625±0.42960739		0.782	0.372
2	4.5625±0.273010732		0.487	0.661
3	4.9375±0.133215597		0.730	0.649
4	5±0		-	-
impact on work	8.9375±0.92230357	0.31154381		
1	3.625±0.579653703		-.090	-.298 ^a
2	1.5±0.435080317		-.257	.016
3	1.375±0.383018973		.037	-.490 ^a
4	2.4375±0.614334331		-.139	-.164 ^a
development opportunity	14.5±1.403091861	0.654		
1	4.4375±0.3352519		0.259	0.685
2	3.4375±0.582707212		0.571	0.477
3	3.1875±0.557811314		0.461	0.567
4	3.4375±0.582707212		0.487	0.548

Table 6.47 continues

the degree of freedom at work	12.5625±1.23011217 5	0.7005473		
1	3.375±0.383018973		.432	.668
2	3.3125±0.422666588		.558	.590
3	3.125±0.266431193		.396	.698
4	2.75±0.567275329		.649	.532
meaning of work	13.1875±0.91715818 2	0.74261603		
1	4.625±0.266431193		.748	.559
2	4.625±0.266431193		.748	.559
3	3.9375±0.531751098		.484	1.000
commitment to work	13.5625±1.44258816 3	0.6943339		
1	3.125±0.579653703		.349	.729
2	2.875±0.471615825		.462	.640
3	3.6875±0.465302075		.467	.638
4	3.875±0.471615825		.684	.501
predictability	5.625±1.008692218	0.74418605		
1	2.5±0.645328397		.622	-
2	3.125±0.471615825		.622	-
role clearance	16.0625±0.98194745 5	0.55623722		
1	2.875±0.510176893		.589	.203
2	4.375±0.329915985		-.008	.710
3	4.1875±0.349082483		.365	.467
4	4.625±0.266431193		.587	.354
role conflict	10.5625±2.01239344 5	0.72217353		
1	3.0625±0.813233665		.364	.772
2	2.3125±0.746482959		.666	.556
3	2.5625±0.582707212		.559	.642
4	2.625±0.546021464		.533	.660
leadership quality	12.625±2.429252548	0.95001337		
1	3.3125±0.637025041		.852	.942
2	3.125±0.611438788		.917	.924
3	3.1875±0.651713427		.881	.934
4	3±0.701545931		.873	.938
social support	12.8125±1.59525329 3	0.73640167		
1	3±0.389147665		.540	.688
2	3.1875±0.485216971		.348	.767

Table 6.47 continues

	3	3.125±0.611438788		.611	.626
	4	3.5±0.615296484		.677	.579
feedback		5.8125±0.957547432			
	1	3.125±0.611438788	0.62967742	.468	-
	2	2.6875±0.504346109		.468	-
social relations		8.5±0.99213577			
	1	4.5±0.514793973	0.61538462	.456	-
	2	4±0.645328397		.456	-
sense of community		10.5625±0.932509176			
	1	3.5625±0.3352519	0.78367347	.787	.545
	2	3.25±0.364014309		.605	.725
	3	3.75±0.41275343		.510	.847
job nonguaranteed		10.5±2.351044566			
	1	3.1875±0.896281292	0.74600457	.579	.668
	2	1.875±0.611438788		.540	.698
	3	2.75±0.836893699		.626	.636
	4	2.6875±0.746482959		.450	.735
job satisfaction		10.6875±1.315623455			
	1	2.6875±0.422666588	0.83845979	.677	.793
	2	2.25±0.456316086		.708	.782
	3	2.625±0.42960739		.750	.759
	4	3.125±0.266431193		.619	.833

COPSOQ method has been applied in this section. Each dimension in the COPSOQ method has been analyzed. The status of psychosocial risks in the laboratory have been investigated.

6.5.3 Result evaluation

Five ergonomic risk assessment methods have been used in this study. In this section, the evaluation results of the five ergonomic risk assessment methods are given. In the following sections there are Evaluation of User Survey for Ergonomic Risks Method, Evaluation of Cornell Musculoskeletal Discomfort Questionnaire Method, Evaluation of Rapid Entire Body Assessment Method, Evaluation of Computer Workstation Checklist Method and Evaluation of Copenhagen Psychosocial Questionnaire Method.

6.5.3.1 Evaluation of User Survey for Ergonomic Risks Method

In USGBC method, there are 15 questions. These 15 questions are grouped into 3 categories. These categories are about workstations questions, about computer workstations questions and about environmental questions.

93 percent of the laboratory employees is not satisfied for speech privacy level and background noise. This is a fairly high rate. Noise affects the performance of employees, their health and work efficiency negatively. So, necessary intervention should be made for this problem. 87% of the employees are dissatisfied with the other factor is working environment temperature and ventilation.

Glare on the screen(s) was found to be another factor that reduced employees' satisfaction level by 53%. For this problem, screen anti-reflection device should be used. The fact that the work materials and the tools such as mouse and keyboard are not in easy reach zone constitutes an important problem for the employees (53% unsatisfied percentage) 67% of employees stated that they had a musculoskeletal system pain. Unsuitable chair using, long standing work and lack of neutrality posture in the workstation are reasons for dissatisfaction among employees. Especially, long standing working is highly effective in the formation of musculoskeletal disorders. So that supporting foot or shoes support for feet is provided (unsatisfied percentage 80%).

6.5.3.2 Evaluation of Cornell Musculoskeletal Discomfort Questionnaire Method

The body parts with the frequent musculoskeletal disturbance among laboratory technicians are as follows respectively: lower back (80%), upper back (80%), neck (73.3%), right knee (66.7%), right shoulder (60%), right foot (53.3%), left shoulder (46.7%), right thigh (46.7%), hip (40%), left foot (40%), right wrist (40%), right upper arm (33.3%), left upper arm (26.7%), right forearm (26.7%), left wrist (26.7%), right lower leg (20%), left knee (20%), left forearm (13.3%), left thigh (13.3%), left lower leg (6.7%).

Lower back pain is the most common occupational musculoskeletal system disorders. The two most important factors that play a role in the formation of musculoskeletal disorders are repetitive strain injuries and cumulative trauma disorders. Although musculoskeletal disorders usually occur as a result of long working time, they can develop in a shorter time in case of extreme strain. (Bilir, 2007)

Durmaz & Öncü (2015) investigated in their studies whether personal factors are influential in the formation of musculoskeletal disorders in upper extremity. According to their study, the increased age does not cause the pain of these body parts to increase. The severity of neck pain and elbow pain were found to be higher in women than in men. They stated that according to many studies, because women are more affected by psychosocial factors than men, and because the autonomic system is activated by stress hormones, pain is more prevalent among women. They noted that there are different results in the literature on the effect of length and weight on pain and gave some study results.

Atasoy et al.,2010 reached some findings about occupational musculoskeletal system disorders in laboratory staff. The most common areas of complaints of pain from musculoskeletal system in the past year were found as follows: upper back (71%), shoulder (71%), lower back (65%), neck (65%), wrist (59%) (Atasoy et al.,2010). Risk factors for neck and shoulder are working in static posture and flexion (Durmaz & Öncü, 2015). In shoulder, lower back and pain in any part of the body are increasing due to difficult physical working conditions (Smith et al.,2006). Aghilinejad et

al.,2012 reported that musculoskeletal disorders related to work are more frequent than other body parts in the neck, shoulder and lower back.

Sirzai et al. (2015) performed a study on work-related musculoskeletal system disorders in hospital employees. Work-related back and upper extremity pain were determined in the following order: neck, back, shoulder, hand-wrist and elbow. The risk factors that are effective in the formation of work-related musculoskeletal disorders are as follows: high BMI ratio, not stopping at the proper position while working, or working hard at a position for a long time, spending extra time to finish the job, doing difficult tasks at work and ergonomically not working environment. They determined that not working at the proper position during exercise was a risk factor for neck, shoulder, back and wrist pain. Working for a long time in a position causes shoulder pain. Ergonomically inappropriate working environment and being tired at the end of the job are risk factor for upper back pain, spending extra time to finish the job is a risk factor for elbow. Performing difficult tasks while working can cause back and elbow pain. (Sirzai et al.,2015)

6.5.3.3 Evaluation of Rapid Entire Body Assessment Method

The weighted REBA score is 6.1322. This score is in medium risk range. Further investigation should be done and some changes should be applied. REBA scores of all sub-tasks were calculated and risk levels were determined. Risk scoring averages and risk levels of main tasks were also identified.

According to the findings, 6 percent of sub-tasks is in the negligible risk group.12 percent of sub-tasks is in the low risk group. 42 percent of sub-task in the medium risk group.32 percent of sub-tasks is in the high risk group. 7 percent of the sub-tasks in the very high risk group.

When the risk levels of 22 main business steps are examined, 36% of the main tasks is at high risk level, 59% of the main tasks is at medium risk level and 5% of the main tasks is at low risk level. More detailed analysis should be done for 39% of the main tasks. With detailed analysis, the necessary arrangements must be made for sub-task in medium risk group. More detailed investigation should be done for 59% of the main tasks. Necessary changes must be applied immediately.

6.5.3.4 Evaluation of Computer Workstation Checklist Method

The VDT method has been applied to a total of 23 sub-tasks in 6 computer workstations (Table 7.44 and Table 7.45). The VDT method is composed of two parts. There are 9 questions in section A-J (VDT1). In section VDT2, there are 23 questions. The answer of any question on the VDT checklist list is “YES”. In application of VDT, 88 “YES” responses and 104 “NO” responses were obtained for 6 computer workstations in total.

This score that was significantly lower than the VDT passing score. Ergonomic inconveniences were found in computer workstations. The necessary interventions must be implemented to increase the VDT score. Some study materials in the application laboratory were identified as ergonomically inappropriate. Especially the chairs used at computer workstations did not get enough passing score. Deficiencies like lack armrest, non-adjustable chair height and back support were led to low scores taken. The fact that there is not enough foot space in the workstation is also an important problem and this problem is encountered in the application laboratory. The necessary interventions must be made to solve this problem and adequate foot space must be provided to the employees.

Another problem seen in the application laboratory is that the computer input devices are not suitable for ergonomics. Wrist support for mouse and keyboard should be provided for sharp edges. Unable to adjust the height of computers in standing computer workstations is an important problem. These computers, which cannot be adjusted according to the person, cause neck and shoulder discomfort in employees.

6.5.3.5 Evaluation of Copenhagen Psychosocial Questionnaire Method

The COPSOQ questionnaire has 20 psychosocial dimensions. 70% of these dimensions have been found in the low risk group. 10% of these dimensions have been found in the medium risk group. 20% of these dimensions have been found in the high risk group.

According to the questionnaire findings, Quantitative Demands, Cognitive Demands, Sensorial Demands and Influence at Work dimensions are high risk group.

Predictability and Feedback at Work dimensions are medium risk group. Emotional Demands, Demands for Hiding Emotions, Possibilities for Development, Degree of Freedom at Work, Meaning of Work, Commitment to the Workplace, Role Clarity, Role Conflicts, Quality of Leadership, Social Support, Social Relations, Sense of Community, Insecurity at Work and Job Satisfaction dimensions are low risk group.

In some dimensions, percentages of high risk group is more than other psychosocial dimensions. These dimensions are sensorial demands, influence at work and cognitive demands dimensions. In sensorial demands dimension, 100% of the questions are in the high risk group. In influence at work dimension, 100% of the questions are in the high risk group. In and cognitive demands dimension, 80% of the questions are in the high risk group.

6.6 Phase 6: Integrated ergonomic risk assessment using IERAMCA

This section describes the integrated ergonomic risk assessment using IERAMCA. The topics in this section are as follows: Creating a Common Scale for All Risk Assessment Methods and Evaluation of Results with Common Scale and Interpretations. The following section describes how to create the common scale.

6.6.1 Creating a Common Scale for All Risk Assessment Methods

In the risk management instruction (DEU, 2014) of Dokuz Eylül University, the risks are classified as low, medium and high risk. This classification has been taken into account when establishing a common scale for the five risk assessment tools used in this study. According to Dokuz Eylül University risk management instruction, the risk levels and their strategy are as follows in Table 6.48.

Table 6.48 Risk Levels and Strategy (DEU, 2014)

Risk Level	Strategy
Low Risk Level	Risks that may have little impact on achieving strategic objectives. The effects are usually small and cover a limited area.
Medium Risk Level	Risks that may have a certain level of impact in reaching strategic targets. It is necessary to define the criteria for key risks that may affect the strategic objectives, as well as being included in this range.
High Risk Level	Risks that can be an important influence in reaching strategic targets. In case of actualization, it is the risk that it may deviate from the goals of the staff so that they cannot fulfill their aims adequately.

There are risk-level scales consisting of different levels of five methods used for evaluation. In Table 6.49, these risk levels have been transformed into common scales according to the hospital's strategic plan.

When the common scale was created, it has been calculated on the basis of the numbers of “NO” answers in the VDT and USGBC method. The VDT method has been studied by creating two different scales. Because the section where the questions A-J and questions 1-23 on the VDT checklist have different evaluation conditions. It

was assumed that these two VDT parts have equal importance when it comes to the weight account. Likewise having four different evaluation interval COPSOQ method has been assumed to be equal importance of the 20 dimensions and has been made of COPSOQ weight calculation method according to this assumption.



Table 6.49 Common risk scale

Risk Level	Ratings	Normalized Ratings
COPSOQ I		
Low	$4 \leq Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW \leq 11$	$0 \leq Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW \leq 0.4375$
Medium	$11 < Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW < 13$	$0.4375 < Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW < 0.5625$
High	$13 \leq Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW$	$0.5625 \leq Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW$
COPSOQ II		
Low	$3 \leq E, M, SC \leq 8$	$0 \leq E, M, SC \leq 0.416667$
Medium	$8 < E, M, SC < 10$	$0.416667 < E, M, SC < 0.5833$
High	$10 \leq E, M, SC$	$0.5833 \leq E, M, SC$
COPSOQ III		
Low	$2 \leq H, P, F, SR \leq 5$	$0 \leq H, P, F, SR \leq 0.375$
Medium	$5 < H, P, F, SR < 7$	$0.375 < H, P, F, SR < 0.625$
High	$7 \leq H, P, F, SR$	$0.625 \leq H, P, F, SR$
COPSOQ IV		
Low	$4 \leq J \leq 9$	$0 \leq J \leq 0.416667$
Medium	$9 < J < 11$	$0.416667 < J < 0.5833$
High	$11 \leq J$	$0.5833 \leq J$
REBA		
Low	$1 \leq REBA \leq 3$	$0 \leq REBA \leq 0.17$
Medium	$3 < REBA \leq 7$	$0.17 < REBA \leq 0.5$
High	$7 < REBA$	$0.5 < REBA$
USGBC		
Low	$0 \leq USGBC < 1$	$0 \leq USGBC < 0.067$
Medium	$1 \leq USGBC \leq 5$	$0.067 \leq USGBC \leq 0.3$
High	$5 \leq USGBC$	$0.33 \leq USGBC$
VDT 1		
Low	$0 \leq VDT1 < 1$	$0 \leq VDT1 \leq 0.11$
Medium	$1 \leq VDT1 < 2$	$0.11 \leq VDT1 < 0.22$
High	$2 \leq VDT1$	$0.22 \leq VDT1$
VDT 2		
Low	$0 \leq VDT2 < 1$	$0 \leq VDT2 < 0.043$
Medium	$1 \leq VDT2 < 3$	$0.043 \leq VDT2 < 0.13$
High	$3 \leq VDT2$	$0.13 \leq VDT2$
CORNELL		
Low	$CORNELL < 720$	$CORNELL < 0.4$
Medium	$720 \leq CORNELL \leq 1440$	$0.4 \leq CORNELL \leq 0.8$
High	$1440 < CORNELL$	$0.8 < CORNELL$

In Table.6.50, the scale of integrated ergonomic risk assessment methods has been created by collecting separately normalized risk score ranges for five methods. In this table normalized ratings are multiplied by the weight of the methods.

Table 6.50 The scale of integrated ergonomic risk assessment methods

Risk Level	Normalized Ratings	Method Weights Multiplied by Normalized Ratios
COPSOQ I		
Low	$0 \leq Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW \leq 0.4375$	$0 \leq Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW \leq 0.0398$
Medium	$0.4375 < Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW < 0.5625$	$0.0398 < Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW < 0.051$
High	$0.5625 \leq Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW$	$0.051 \leq Q, C, S, I, D, DF, CW, R, RC, QL, SS, IW$
COPSOQ II		
Low	$0 \leq E, M, SC \leq 0.416667$	$0 \leq E, M, SC \leq 0.009$
Medium	$0.416667 < E, M, SC < 0.5833$	$0.009 < E, M, SC < 0.0133$
High	$0.5833 \leq E, M, SC$	$0.0133 \leq E, M, SC$
COPSOQ III		
Low	$0 \leq H, P, F, SR \leq 0.375$	$0 \leq H, P, F, SR \leq 0.0114$
Medium	$0.375 < H, P, F, SR < 0.625$	$0.0114 < H, P, F, SR < 0.019$
High	$0.625 \leq H, P, F, SR$	$0.019 \leq H, P, F, SR$
COPSOQ IV		
Low	$0 \leq J \leq 0.416667$	$0 \leq J \leq 0.0032$
Medium	$0.416667 < J < 0.5833$	$0.0032 < J < 0.004$
High	$0.5833 \leq J$	$0.004 \leq J$
REBA		
Low	$0 \leq REBA \leq 0.17$	$0 \leq REBA \leq 0.055$
Medium	$0.17 < REBA \leq 0.5$	$0.055 < REBA \leq 0.163$
High	$0.5 < REBA$	$0.163 < REBA$
USGBC		
Low	$0 \leq USGBC < 0.067$	$0 \leq USGBC < 0.016$
Medium	$1 \leq USGBC \leq 0.3$	$0.016 \leq USGBC \leq 0.072$
High	$0.33 \leq USGBC$	$0.072 \leq USGBC$
VDT 1		
Low	$0 \leq VDT1 \leq 0.11$	$0 \leq VDT1 \leq 0.0075$
Medium	$0.11 \leq VDT1 < 0.22$	$0.0075 \leq VDT1 < 0.015$
High	$0.22 \leq VDT1$	$0.015 \leq VDT1$
VDT 2		
Low	$0 \leq VDT2 < 0.043$	$0 \leq VDT2 < 0.043$

Table 6.50 continues

Medium	$0.043 \leq \text{VDT2} < 0.13$	$0.043 \leq \text{VDT2} < 0.13$
High	$0.13 \leq \text{VDT2}$	$0.13 \leq \text{VDT2}$
	CORNELL	
Low	$\text{CORNELL} < 0.4$	$\text{CORNELL} < 0.4$
Medium	$0.4 \leq \text{CORNELL} \leq 0.8$	$0.4 \leq \text{CORNELL} \leq 0.8$
High	$0.8 < \text{CORNELL}$	$0.8 < \text{CORNELL}$

In Table 6.51, the scale of the integrated system is the sum of all ranges of each method. Prevention levels are given in this table. according to DEU (2014) risk classification, integrated method scale has been created. If the result is in low risk class, it is acceptable as negligible risk. In case of medium risk, further investigation and changing soon are necessary. In case of high risk, changing should be implemented immediately.

Table 6.51 Integrated Method Scale

Integrated Method Scale		
Low	$0 \leq \text{IM}^* < 0.2984$	Negligible
Medium	$0.2984 < \text{IM}^* \leq 0.4663$	Further investigation, change soon
High	$0.4663 < \text{IM}^*$	Implement change immediately

*Integrated model risk score

In Table 6.52, according to the results of the integrated method scale, there are the application results of the real-life problem. In the table, there are the weights of each method. The application result of each method is shown in this table. Application results have been normalized. Method weights have been multiplied by normalized results. The results obtained for all methods have been collected and a final risk score has been obtained. The risk class for which this final risk score corresponds to the integrated method scale is determined.

Table 6.52 Integrated model risk score

Ergonomic Risk Assessment Methods	Weights	Results of Risk Assessment	Normalized Results	Method Weights Multiplied by Normalized Ratios
COPSOQ I	0.098488	155.13	0.496	0.048833633
COPSOQ II	0.022728	20.6	0.32	0.007323467
COPSOQ III	0.030304	20.6	0.396	0.0119322
COPSOQ IV	0.007576	9.33	0.44	0.003367111
REBA	0.32561	6.13	0.438	0.11949887
USGBC	0.23952	7.87	0.524	0.125614933
VDT 1	0.067825	3.5	0.389	0.026376389
VDT 2	0.067825	17.33	0.754	0.051114493
CORNELL	0.1477	125.3	0.0696	0.010281561
INTEGRATED MODEL RISK SCORE				0.404342657

According to the calculations made, the integrated system has a risk score of 0.404. It is in medium risk class according to scale. It should be done further investigation and changes should be applied.

6.6.2 Evaluation of Results with Common Scale and Interpretations

This section describes the common scale structure, which is a phase of the proposed methodology in this study. Five ergonomic risk assessment methods have separate evaluation scales. To obtain a final result, these scales must be integrated on a common ground. In this section, a common evaluation scale has been established. The risks in the common evaluation scale are classified as low, medium and high. This classification has been determined according to the risk strategy of the application institution. The results of the evaluation of the five methods applied in the laboratory have been normalized. And these values have been multiplied by the weights obtained from ANP. These values have been collected, and an integrated model risk score has been obtained. The result obtained has been evaluated on the common scale. The risks in the laboratory are in the medium risk class. So, the risks in the laboratory should be investigated better and some intervention suggestions related to the laboratory should be done in the working environment. Some intervention recommendations for the laboratory are given in the next section.

6.7 Phase 7: Recommendations of Possible Intervention

In this section, possible intervention recommendations are made according to the results of the ergonomic risk assessment carried out in the laboratory. According to the integrated risk model application result, the tasks in the blood center laboratory are in the medium risk class. It is necessary to take some precautions by making some changes in this risk group.

Laboratory ergonomics include industrial risks in terms of working with hazardous materials such as biological and chemical materials. In addition, it includes the risk of office environment such as repetitive movements, contact stresses, vibrations and working with fingertips, long working in bad and static postures, etc. Factors that cause a work-related musculoskeletal disorder to occur are bad posture, repetitive motion and combination of forces. Work posture includes static or dynamic body positions. Spending long hours in front of a computer or microscope is the most obvious example of static activities in the laboratory environment. These static activities cause ischemic contractions in the muscles, causing pain and discomfort in the affected muscle group. Some ergonomic control measures to be taken in the laboratory environment. (Babayigit & Kurt, 2013) Possible interventions are divided into three: behavioral measures, engineering measures and organizational measures.

6.7.1 Recommendation of Behavioral Measures

Behavioral interventions are directly related to employees. Employees should be informed about employee 's health and safety. Individual instructions are not enough to ensure sustainable impact. For this purpose, trainings should be arranged to employees at regular intervals. (European Commission, 2014) Some behavioral measures to be taken in the workplace is as follows:

- Employees should be informed about occupational safety and health and trainings should be organized.
- Employees must be ensured to attend trainings.
- Employees should be informed about occupational safety and health.
- Employees should be encouraged to do physical exercise.

Employees do not do things as they should due to the workload and hurry of the employees, but they find the short way to work. This situation causes employees to work in non-ergonomic postures. And inappropriate postures lead to musculoskeletal disorders. So, as an organizational measure the workload should be evenly distributed. As a behavioral measure, employees should be educated for this situation. In this study, in application laboratory, a sub-task of “infection test” main task (no: 9), some employees do not use the chair because of time pressure. This sub-task is “the label on the tube is read through the label reader” (Figure 6.58). If this sub-task is done using the chair, the REBA score becomes 4. Although employees generally use the chairs, some employees sometimes do not use them. In this case, REBA score is 6 points. The average REBA score of the Infection test main task is 4.8. If this sub-task is not performed correctly, the average REBA score of this main task is increased to 5.



Figure 6.58 Bad posture (main task no:9, sub-task no:5) (Personal archive, 2018)

Laboratory technicians are exposed to many risks such as psychosocial risks due to their work. Training should be given in certain periods to ensure that employees are minimally affected by such risks. Employers should provide the employees a suitable working environment by making improvements while eliminating or lessen the effects

of the ergonomic risk factors where continuous monitoring of the ergonomic risk factors is needed in order to compare the improved system with the current system.

6.7.2 Recommendation of Engineering Measures

Engineering measures include reducing the impact of risks or eliminating risks with technical applications, technical designs, technical interventions or construction interventions (European Commission, 2014).

Some laboratory equipment such as pipette, microscope, microtome can cause health and productivity affect and causing upper extremity disorders because of repetitive work. So ergonomically designed working equipment should be used. The pipette from the laboratory equipments mentioned above is frequently used in the blood center laboratory. There are some intervention recommendations regarding the use of this equipment below (Babayigit & Kurt, 2013):

- In more repetitive jobs, electronic, automatic pipettes should be preferred.
- Pipettes must be of different lengths and shapes.

In Figure 6.59 and Figure 6.60, there are photos about incorrect-correct pipetting and ergonomically designed pipettors (Dorsey, 2012). Ergonomically designed pipettes reduce the REBA score of the pipetting process by 5 (medium risk level) to 3 (low risk level). The average REBA score of this main task (main task no:18) is 4.26. With the use of an ergonomic pipette, the average of the main task decreases to 4.



Figure 6. 59 Incorrect and correct pipetting (Dorsey, 2012)



Figure 6.60 Ergonomically designed pipettors (Dorsey, 2012)

There are ergonomic extractors for opening the tube covers. Cover extractors should be used to keep pinches and minimize stress (Figure 6.61). The use of a cover extractor for tubes reduces the coupling score in REBA analysis. As a result of the decrease in the coupling score, the REBA results are reduced.



Figure 6.61 Microtube opener of Gilson's Jimmy (Dorsey, 2012)

Laboratory workbenches are very important in terms of posture disorders. In particular, inappropriate workbenches lead to the formation of musculoskeletal disorders. Laboratory benches should be designed in accordance with the ergonomic conditions of the workers since the heights of the benches are fixed. In Figure 6.62, it is shown that inadequate workbench height related to the laboratory. It is not easy to change the height of the work benches because the hospital where the case application is made is a state hospital. So, the height of the chairs used when working on these benches must be adjustable. (Dorsey, 2012).



Figure 6.62 Inadequate workbench height (Personal archive, 2018)

In Figure 6.63, because the machine size is fixed, it should be a feet platform for the convenience of short employees. On this account, bending is avoided.



Figure 6.63 Machine height (Personal archive, 2018)

The contact stress risk is encountered especially in computer workstation. Some precautions should be taken to ensure that employees are minimally affected by this risk. Use of the edge rest provides protection from sharp edges. In Figure 6.64, there are ergonomically inadequate chair sample. The sub-task (main task no: 10, sub-task no:5) in this photo is one of the sub-tasks of witness sample separation main task. Usually this sub-task is done by working standing. When this sub-task is done by working standing, the REBA score is 4 (medium risk). If this sub-task is done using the chair the REBA score for this task is 9 and is in the high risk class. If an ergonomically designed chair is provided, the risk score for this task is reduced to 3. The risk class of this task is reduced to the low risk class.



Figure 6.64 Ergonomically inadequate chair (Personal archive, 2018)

In Figure 6.65, a non-ergonomic workstation is shown in the application laboratory. There are not sufficient knee and leg space in this workstation (Workstation 6). It should be arranged ergonomically designed workstation for this problem. Sufficient knee and leg space should be provided.



Figure 6.65 Insufficient leg space (workstation 6) (Personal archive, 2018)

Example of some of the ergonomic risks mentioned are in Figure 6.66 and Figure 6.67. Reaching is ergonomically dangerous and it can cause musculoskeletal disorders. If a mechanism is designed for the task in the Figure 6.67 reaching is eliminated. Removal of Filtered Erythrocytes (main task no:4) main task is in high risk class. This risk class can be reduced to low risk class with an ergonomically designed mechanism for hanging erythrocyte bags.

The negative effects of heavy lifting, which is a common occurrence in the laboratory, can be reduced by a carrying material with ergonomically suitable holders (Figure 6.67). The REBA score for this sub-task (main task no:11, sub-task no:3) is 8 and is in the high risk class. If carrying material with ergonomically suitable holders is provided, the risk score for this task is reduced to 2. The risk class of this task is reduced to the low risk class. “Loading distile water to the autoanalyzer” main task’s average REBA score decreases from 8 to 7.2 through this improvement.



Figure 6.66 Example of a sub-task (Personal archive, 2018)



(a)

(b)

Figure 6.67 Heavy lifting in the laboratory ((a) Ergo Products, n.d.; (b) Personal archive, 2018)

Furthermore, a laboratory stool with ergonomic waist and lumbar support should be used. The back should be supported by an ergonomic back support. Especially,

sufficient knee and leg space must be available at workstation. If it is a standing work bench, supportive shoes and anti-fatigue mat should be used. (Mitchell, 2010b)

Musculoskeletal disorders are common in laboratory workers because of such situations. So, it is very important to provide a suitable working environment for laboratory staff. Below there are some suggestions to provide an ergonomically comfortable working environment for laboratory staff (Babayiğit & Kurt, 2013):

- The work posture should be neutral or natural, such that the shoulders are comfortable, parallel to the angle of the elbow and forearm.
- The working environment must have proper lighting, air quality (temperature, humidity, etc.), radiation, noise, heating and ventilation qualities.
- Table with adjustable height, suitable width and comfort, exercise chair with back and lumbar support should be used.
- The worktable with appropriate height and width must be designed so as not to interfere with work movements.
- Instead of long working hours, short working times and short periods of work and rest periods should be set.

There are some intervention recommendations regarding the use of this equipment below (Babayiğit & Kurt, 2013):

- Short breaks should be given every 20 minutes in long pipetting periods.
- Samples or equipment should be kept in an easily accessible location.
- Support arrangements should be made so that the arms are not kept on the ground continuously.
- To avoid shoulder muscles being exposed to chronic contractions, the arms should be kept as close to the body as possible, in the neutral position.
- In the use of all these tools and devices, anthropometric work place design or ergonomic tool design should be used during posture improvement. (Dorsey, 2012).
- Work materials must be located (to minimize the reach distance and not to wist) at a distance that the employee can reach easily.

- Both hands must be used during opening and closing of the tube caps to reduce stress in one hand.

Another important ergonomic issue in the laboratory is the handling of test tubes (Figure 6.68). Body posture has an importance in the tube handling. The chair should be brought to the optimum level for the worker before starting to work in the handling of the test tube. Because it is important to provide back support for this workgroup in terms of work comfort. (Dorsey, 2012)



Figure 6.68 Handling of test tubes (Dorsey, 2012)

To summarize the recommended engineering measures;

- With the use of an ergonomic pipette, REBA scores of the two sub-tasks (Main task no:18, sub-task no:3 and sub-task decrease from 5 (medium risk) to 3 (low risk).
- Removal of filtered erythrocytes (main task no:4) main task is in high risk class. This risk class can be reduced to low risk class with an ergonomically designed mechanism for hanging erythrocyte bags.
- The sub-task (main task no: 10, sub-task no:5) is done by working standing. When this sub-task is done by working standing, the REBA score is 4 (medium risk). If this sub-task is done using the chair the REBA score for this task is 9 and is in the high risk class. If an ergonomically designed chair is provided, the risk score for this task is reduced to 3. The risk class of this task is reduced to the low risk class.
- If ergonomic extractors is used for opening the tube covers; The risk score for sub-task:4 (main task no:12) is reduced from 6 to 5.

The risk score for sub-task:8 (main task no:14) is reduced from 6 to 5.

The risk score for sub-task:14 (main task no:14) is reduced from 6 to 5.

The risk score for sub-task:5 (main task no:15) is reduced from 6 to 5.

The risk score for sub-task:11 (main task no:15) is reduced from 6 to 5.

The risk score for sub-task:3 (main task no:16) is reduced from 9 to 7.

- The REBA score for a sub-task (main task no:11, sub-task no:3) is 8 and is in the high risk class. If carrying material with ergonomically suitable holders is provided, the risk score for this task is reduced to 2

So, the laboratory staff likely experience the work-related musculoskeletal disorders due to the frequent occurrence of ergonomic risks in laboratory environment. Hence, it is really important to analyze the working environment from the ergonomic perspective and sequentially to provide suggestions for improvements.

6.7.3 Recommendation of Organizational Measures

Organizational measures include prevention of risks through good working organization ergonomically and with work sequences arrangements (European Commission, 2014). The two most important organizational measures are related to work schedules and workload distribution. Irregular work schedules (eg work shifts and shifts) affect workers' sleep and eating habits, family and social communications, and work accidents. As the workload of the employee increases, the work pressure on the employee increases and the performance demands increase. This work pressure will also cause the employee to be encouraged to take a short way of work by taking various risks. As a result, the possibility of muscle and musculoskeletal disorders will increase. In addition, the overtime employee can cause fatigue and cannot react to events. So, the possibility of work accidents increases. (WCB office ergonomics, n.d.)

Employees express the following situations:

- They have to keep working at a high pace.
- The workload is not evenly distributed.
- They have not enough time to complete all tasks.
- They have to work overtime.
- They have to pay much attention to work.
- They cannot determine the amount of work given.
- Their work requires constant attention.
- They need to work without errors.

For all these reasons as mentioned above, supervisor should do the work distribution fairly. Rotational work should be carried out and short periods of rest should be given at frequent intervals (Babayigit & Kurt, 2013).

CHAPTER SEVEN

CONCLUSIONS

As the consumption rate is increasing day by day, the workload of the production and service sector workers is increasing. It is necessary to make ergonomic adjustments in order to improve these inappropriate working conditions. Ergonomic improvements are possible reducing the occupational discomfort of employees, reducing staff turnover rate, increasing job satisfaction, reducing the compensation costs of employees. (Ayanoğlu, 2007) Occupational musculoskeletal system diseases are one of the most important health problems of employees and affect productivity adversely, but it is possible to prevent from the negative effects of these diseases by ergonomic adjustments (Daneshmandi et al., 2017).

In developed countries, the frequency and cost of work-related musculoskeletal disorders are increasing rapidly because of the reasons mentioned above. Therefore, in these countries studies on risk factors that affect the development of musculoskeletal diseases, loss of labor and its costs have accelerated in recent years. In these countries, if occupational musculoskeletal diseases are diagnosed as occupational diseases, disability must be determined, and compensation must be paid. Due to these reasons, legal regulations are being implemented in developed countries to prevent occupational musculoskeletal disorders and ergonomics training for this purpose is being implemented. (Piedrahita, 2006)

Musculoskeletal diseases involve a wide range of health problems. A major part of these diseases is caused by back disorders and work-related upper limb disorders. Lower limb disorders can also be encountered. Musculoskeletal disorders are highly associated with work. To avoid musculoskeletal disorders:

- Firstly, all risk factors in the workplace must be determined.
- Then, measures should be taken to reduce the impact of risks or the prevention of risks.

The types of risks faced by employees in each workplace and every profession are very different. So, the workplace and employees must be thoroughly examined to find

solutions to these risks. All risk factors should be carefully examined. Because, some factors may combine, and they can create a risk type.

In this study, occupational musculoskeletal system disorders of a hospital's blood center laboratory have been investigated. Discomfort information about the employees has been obtained by the subjective assessment methods. However, the subjective assessment methods have been deemed inadequate in determining these conditions. For this reason, the hospital's occupational health and safety unit has been consulted. From this unit, information on musculoskeletal disorders related to employees is obtained. In this study, occupational musculoskeletal system disturbances were determined by the systematic approach using employees' self-reports and available records.

While investigating the risks of work-related musculoskeletal system, in addition to the method of subjective judgement, the risks related to work can be determined with observer evaluation methods and more detailed analysis can be made. At this point, risk management is analyzed from proactive and reactive aspects. The effects of psychosocial factors in the formation of occupational musculoskeletal disorders are quite high. It has been stated in many studies that psychosocial factors are a very important risk factor. Stress management must also be found within the ergonomic improvements to be made at the workplace because there are ergonomic risk factors in the source of work-related stress (CDC, n.d.). So, psychosocial risks should also be considered in the analysis of musculoskeletal disorders related to work.

Therefore, in this study the risks of musculoskeletal disorders in the laboratory has been determined. Each of these risks is evaluated with different assessment methods. Therefore, five ergonomic risk assessment methods have been selected for this study. These methods have been applied separately. A common scale has been created to evaluate the results of the application. While creating this scale, ANP method which is a multi-criteria decision making method has been chosen to determine the weights of the methods.

The weights of five ergonomic risk assessment methods have been determined by ANP method. With the weights determined by ANP, a common scale has been formed.

The evaluation results of the methods have been evaluated on the common evaluation scale and a final risk score has been obtained. In this study, this score has been found in the medium risk group according to the common scale. A more detailed analysis should be carried out at the workplace for risks in the medium risk group. Studies should be performed to eliminate or reduce the risks of occupational musculoskeletal disorders.

Recommendations necessary to provide solutions for occupational musculoskeletal system disorders (Luttmann et al., 2003):

- In order to be able to effectively solve a problem related to the musculoskeletal system, it is necessary to observe the actual situation in the workplace. Because, factors that are unique to different workings in the workplace are variable.
- All possible risk factors, especially the combination of the factors that can be brought together by risk, must be taken into account.
- It is not always possible for a single approach to work, and expert advice may be needed if unusual or serious problems arise.

Recommendations for employees (Luttmann et al., 2003):

- It must be kept close to the body while the load is removed.
- Both hands must be used for lifting and the handles must be symmetrically aligned.
- The trunk should be in the upright position when the heavy load is lifted. There should be no bad positions such as bending and twisting.
- Transport and lifting equipment should be used for lifting and transport operations.
- Transportation must be done with two people, not alone.

Recommendations for employers (Luttmann et al., 2003):

- Training on handling should be given.
- Manual handling should be avoided. If it cannot be avoided employees should be given ergonomic requirements and awareness should be provided.
- Transport on slippery floors and stairs should be avoided.

- Ancillary equipment should be provided to facilitate the work of employees.
- Heavy loads must be marked.
- Non-symmetrical loads and with moveable content (fluids etc.) containers should be marked.

One of the preconditions of working efficiently is to provide a healthy and safe work environment for employees and this is one of the decisive elements of social development. As a result, occupational health and safety is very important in the field of health services as well as all business areas. (Savcı et al., 2018) The workplace needs to be ergonomically improved and job processes must be rearranged according to the employees. Employees should be provided awareness by training ergonomics periodically. Supervisors should support for ergonomic improvements. Before and after improvements, the situation should be calculated by making periodic measurements and shared with employees.

It is very important to evaluate physical and psychosocial risks together in ergonomic risk assessment. At the same time, subjective and observational methods should be used together for objective results. In addition, an integrated risk assessment study should be conducted by examining the employee records at the workplace. In this study, an integrated ergonomic risk assessment methodology is proposed to evaluate physical and psychological risks together. Both subjective and observational methods are used in this methodology. The real-life application of the proposed integrated methodology has been performed. The application has been performed at the blood center laboratory of a university hospital. According to the results of the application, an integrated risk score has been obtained. According to this risk score, behavioral, engineering and organizational intervention recommendations have been given.

Behavioral intervention recommendations can enable employees to work in ergonomic postures and the likelihood of employees getting musculoskeletal disorders can be reduced. With engineering intervention recommendation, the risk score of 11 sub-tasks is reduced. Considering the organizational intervention recommendations, the risk class of 4 dimensions in the high-risk class in the COPSOQ method is reduced. The impact of psychosocial risks to laboratory technicians can be reduced. With the

implementation of all these intervention recommendations, significant decreases in the risk levels of some tasks will be observed. Further study should be done for interventions. Work environment should be improved ergonomically with engineering designs. Employees should be provided with regular ergonomics training. The formation of ergonomic awareness in employees should be followed.

In this study, the objectivity of the ergonomic risk assessment has been provided by the proposed methodology. The evaluations made with the existing methods in the literature are not objective sufficiently. With this integrated ergonomic risk assessment methodology, all ergonomic risks that employees are exposed to are evaluated. With this methodology, proactive and reactive approach to risk assessment has been introduced.

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APPENDICES

Table 1. All sub-tasks

	Sub-Tasks
	1.Taking Samples from Whole Blood Bag
1	The lids of the tubes to fill cross match sample are opened.
2	The cross sample hose is torn from the whole blood bag .
3	The tip of the hose is cut with scissors and thrown into the garbage can.
4	The blood is filled into the tube from hose.
5	The lids of the tubes are closed.
6	The cross-match sample is stored.
7	Infection and blood group sample tubes are separated from the whole blood bag.
8	The relevant label on the blood bag is removed.
9	The label is affixed to the cross match sample tube.
10	The infection test sample is left for centrifugation.
11	The blood group sample tube is left for blood group identification process.
	2.Centrifugation of Whole Blood Bags
1	Whole blood taken from the donor is rested on a surface inclined at least one hour at room temperature.
2	Whole blood is placed in the baffles of the refrigerated centrifuge.
3	The baffles are balanced by weighing on the scales.
4	The balanced baffles are placed in a refrigerated centrifuge.
5	Inner cover of the centrifuge machine is closed.
6	Outer cover of the centrifuge machine is closed.
7	The appropriate test program is selected in the centrifuge.
8	The device is started.
9	The operation of the device is followed.
10	Outer cover of the centrifuge machine is opened.
11	Inner cover of the centrifuge machine is opened.
12	Centrifuged whole blood bags are taken from the centrifuge machine.
	3.Erythrocyte and Plasma Separation

Table 1. continues

1	The centrifuged bags are removed from the baffles.
2	Centrifuged whole blood bags and product bags are placed in the extractor.
3	The test program is selected in the extractor.
4	The clamps of the whole blood bag placed in the extractor are broken.
5	The plasma bag's hose is torn off from the main bag system.
6	The erythrocyte suspension is removed from the extractor.
7	The plasma is separated from the extractor.
8	Buffy coat bag is mixed with external intervention with hand.
9	Buffy coat bag and empty platelet bag are removed from the extractor.
10	The buffy coat bag's hose is knotted.
11	The buffy coat is hung to the resting platform and rested for at least one hour at room temperature.
	4. Removal of Filtered Erythrocytes
1	The erythrocyte suspension separated from the extractor is suspended.
2	Erythrocyte through the filter is waited and controlled filling the following bag.
3	When the bottom bag is full, it is turned over again.
4	It is hung again.
5	The bag is controlled and waited for filling.
6	Filtered erythrocyte bag is removed from the hanger.
7	The excess hose of the filtered erythrocyte bag is cut off and the cut parts are sterilized with machine.
8	Unnecessary hose parts are torn off.
9	Unnecessary hose parts are thrown away.
10	The product is held for labeling process.
	5. Platelet Separation
1	Rested buffy coat bags are placed in centrifuge baffles.
2	The baffles are balanced by weighing on the scales.
3	The balanced baffles are placed in a refrigerated centrifuge.
4	Inner cover of the centrifuge machine is closed.
5	Outer cover of the centrifuge machine is closed.
6	The appropriate test program is selected in the centrifuge.
7	The device is started.

Table 1. continues

8	The operation of the device is followed.
9	Outer cover of the centrifuge machine is opened.
10	Inner cover of the centrifuge machine is opened.
11	Centrifuged bufy coat bags are taken from the centrifuge machine.
12	Bufy coat bags are placed in the extractor.
13	The test program is selected in the extractor.
14	The clamps of the bufy coat bags placed in the extractor are broken.
15	The platelets are removed from the extractor.
	6.Labeling of Products
1	The excess hoses of the bags experienced product separation process are cut off and the cut parts are sterilized with machine.
2	Unnecessary hose parts are torn off.
3	Unnecessary hose parts are thrown away.
4	The grazing process is done to the hose in erythrocyte bag.
5	The liquid coming from the hose is mixed in the bag by shaking.
6	The related pages are opened on the computer screen.
7	Barcode on the bag is read via reader.
8	The label output of the product is taken.
9	The labels is read via reader again.
10	Labels are affixed onto the bags.
11	The required sample tube is found from the tube rack.
12	Sample tubes are attached to the erythrocyte bag.
13	Erythrocytes are stored in +4°C cabinet.
14	Thrombocytes are kept at room temperature in 20-24°C agitators(platelet storage cabinet) for a maximum of 5 days.
15	Plasmas are stored in deep freeze.
	7.Plasma shocking process
1	Plasmas are taken from the cabinet.
2	They are inserted into the shocking device.
3	The device is started.
4	Plasmas are removed from the device.
5	Plasmas are stored in deep freeze.
	8.Thrombocyte pooling
1	The desired number of random platelets are removed from the agitator.
2	Random platelets are combined in the sterile connecting device.
3	The pooled platelet is suspended.

Table 1. continues

4	On the pooled platelet bag, the conformity label(blood group, expiration date etc.) of the combined random platelets is affixed.
5	Filtered platelet bag is removed from the hanger.
6	Thrombocytes are kept at room temperature in 20-24°C agitators(platelet storage cabinet) for a maximum of 5 days.
	9. Infection Test
1	The tube is placed in the centrifuge machine.
2	Test program is selected and the device is operated.
3	The operation of the device is followed.
4	The centrifuged tube is removed from the centrifuge machine.
5	The label on the tube is read through the label reader.
6	The tube is inserted into the autoanalyzer.
7	The device is run in the appropriate program.
8	The operation of the device is followed.
9	The sample tubes are taken from the autoanalyzer.
10	The results are checked from the computer.
11	The tubes are waited to receive the witness sample.
	10. Witness sample separation
1	The barcodes of the infection test samples are turned in the same direction.
2	The barcodes of the infection test samples from the autoanalyzer are read and appropriate labels are collected.
3	The empty witness sample tube taken from drawer.
4	The empty witness sample tube is placed on the rack where the infection test samples are.
5	Blood sample is drawn by pipette from infection test samples and filled into witness sample tubes.
6	Labels of witness sample tubes are affixed.
7	The covers of the witness sample tube are closed.
8	Witness sample tube is stored.
9	Infection test samples are discarded.
	11. Loading distile water to the autoanalyzer
1	The disinfectant liquid is removed from the cabinet.
2	Required amount of this liquid is poured into the distile water bin.
3	The bin is moved to the autoanalyzer.
4	The bin is connected to the autoanalyzer with hose.

Table 1. continues

5	After the filling process, the bin is reinserted into the distile water device.
	12.Placement of the solutions required for the operation of the autoanalyzer
1	The outer cover of the autoanalyzer are opened.
2	Inner covers of the autoanalyzer are opened.
3	Empty solution bottles are removed from the autoanalyzer.
4	The lids of the full bottles are opened.
5	The plugs are attached to the bottle openings.
6	The bottles are placed in the respective cells of the machine.
7	The outer cover of the autoanalyzer are closed.
8	Inner covers of the autoanalyzer are closed.
9	The liquid levels within the control tubes are checked.
10	Control liquid is filled into the control tubes.
11	The control tubes are placed in the autoanalyzer.
12	It is checked on the screen that the device is working properly.
	13. Tube Centrifuge in the Microcentrifuge
1	The tube is placed in the centrifuge machine.
2	Test program is selected and the device is operated.
3	The operation of the device is followed.
4	The centrifuged tube is removed from the centrifuge machine.
	14. Erythrocyte reservation
1	The patient's blood samples are taken.
2	The label on the tube is read to see what the doctor wants.
3	The sample tube of the desired product is removed from the cabinet.
4	The tubes are placed in the centrifuge machine.
5	Test program is selected and the device is operated in the centrifuge machine.
6	The operation of the device is followed.
7	The centrifuged tube is removed from the centrifuge machine.
9	The tubes are placed in the plastic tube rack by bringing barcodes on the tube forward.
10	The tube rack is placed in the cross match machine.
11	The device is run in the appropriate program.
12	The operation of the device is followed.
13	The tube rack is taken from the device.
14	The lid of each tube is closed.

Table 1. continues

15	If the cross match test results are acceptable, the reserve label is printed on the product.
16	The relevant tubes are attached to the erythrocyte bag.
17	The product is removed with the tube in the reservation cabinet.
	15. Blood Group Identification Process
1	The tube is placed in the centrifuge machine.
2	Test program is selected and the device is operated.
3	The operation of the device is followed.
4	The centrifuged tube is removed from the centrifuge machine.
6	The tubes are placed in the plastic tube rack by bringing barcodes on the tube forward.
7	The tube rack is placed in the blood group determination device.
8	The device is run in the appropriate program.
9	The operation of the device is followed.
10	The tube rack is taken from the device.
11	The lid of each tube is closed.
12	The label of the result is printed for products.
13	Stored.
	16. Discharge of waste water from cross match and blood group machine
1	The waste water bin is removed from the site.
2	The bin is moved to the sink.
3	The lid is opened.
4	The waste water is poured into the sink.
5	The lid is closed.
6	The bin is moved to its place and placed.
	17. Gel card centrifuge
1	The gel cards are placed in the centrifuge.
2	The appropriate test program is selected in the centrifuge.
3	The device is started.
4	The operation of the device is followed.
5	The gel cards are removed from the device and cards are placed in the box after the device is stopped.
6	Cards are kept for use in blood group and cross machine.
	18. Manual filling of gel cards for blood group and cross match machine operations.
1	The erythrocyte dilution solution is filled into a tube.

Table 1. continues

2	The solution is taken from the tube by injector.
3	The small cells in the gel cards are filled from the dilution solution in the injector.
4	Sample of the centrifuged blood tube to be processed is drawn by injector.
5	Blood sample is squeezed into gel cards.
6	Gel cards are placed in incubator.
7	The device is started.
8	The operation of the device is followed.
9	Cards are removed from incubator.
10	Gel cards set in centrifuge.
11	The appropriate test program is selected in the centrifuge.
12	The device is started.
13	The operation of the device is followed.
14	Cards are removed from the device.
15	Cards is put into the cross or blood group machine.
19. Preparing cross and blood group machines for operating.	
1	Centrifuged gel cards are placed in the machine.
2	The machine's cover is opened.
3	The required liquids (erythrocyte dilution solution, blood group screening cells etc.) are filled into the relevant locations on the machine.
4	The trash box of the machine is emptied.
5	The machine's cover is closed.
6	Things loaded in the machine is introduced to the computer.
20. Plasma and thrombocyte reservation	
1	The desired products for the patients are checked from the computer screen.
2	The desired product is taken out of the closet.
3	The product is booked from the system on behalf of the patient.
4	The patient reserve label is affixed to the product.
5	Products are removed in reserve cabinet.
21. Removal of reservations for products that expire at the end of the reservation.	
1	The list of products that need to be booked down is looked at from the screen.
2	That product is removed from the reservation cabinet.
3	Barcode is read and removed from the system.

Table 1. continues

4	Reserved label is removed.
5	The product is put into the stock cabinet.
	22. Blood irradiation technique
1	The blood products to be irradiated are removed from the cabinets.
2	Products are transported to the ray room.
3	The irradiated products are moved to the lab.
4	The irradiated product labels are adhered to the irradiated products.



Table 2. Pre-risk analysis

Sub-Tasks	Impact Severity Categories		
	Emergency-1	Critical-2	Major-3
1.Taking Samples from Whole Blood Bag			
The lids of the tubes to fill cross match sample are opened.		×	
The cross-match sample hose is torn from the whole blood bag.	×		
The tip of the hose is cut with scissors and thrown into the garbage can.	×		
The blood is filled into the tube from hose.	×		
The lids of the tubes are closed.	×		
The cross-match sample is stored.		×	
Infection and blood group sample tubes are separated from the whole blood bag.		×	
The relevant label on the blood bag is removed.		×	
The label is affixed to the cross-match sample tube.		×	
The infection test sample is left for centrifugation.		×	
The blood group sample tube is left for blood group identification process.		×	
2.Centrifugation of Whole Blood Bags			
Whole blood taken from the donor is rested on a surface inclined at least one hour at room temperature.		×	
Whole blood is placed in the baffles of the refrigerated centrifuge.		×	
The baffles are balanced by weighing on the scales.		×	
The balanced baffles are placed in a refrigerated centrifuge.		×	
Inner cover of the centrifuge machine is closed.		×	
Outer cover of the centrifuge machine is closed.		×	
The appropriate test program is selected in the centrifuge.			×
The device is started.			×
The operation of the device is followed.			×

Table 2. continues

Outer cover of the centrifuge machine is opened.		×	
Inner cover of the centrifuge machine is opened.		×	
Centrifuged whole blood bags are taken from the centrifuge machine.		×	
3.Erythrocyte and Plasma Separation			
The centrifuged bags are removed from the baffles.		×	
Centrifuged whole blood bags and product bags are placed in the extractor.		×	
The test program is selected in the extractor.			×
The clamps of the whole blood bag placed in the extractor are broken.	×		
The plasma bag's hose is torn off from the main bag system.		×	
The erythrocyte suspension is removed from the extractor.		×	
The plasma is separated from the extractor.		×	
Buffy coat bag is mixed with external intervention with hand.		×	
Buffy coat bag and empty platelet bag are removed from the extractor.		×	
The buffy coat bag's hose is knotted.	×		
The buffy coat is hung to the resting platform and rested for at least one hour at room temperature.		×	
4.Removal of Filtered Erythrocytes			
The erythrocyte suspension separated from the extractor is suspended.		×	
Erythrocyte through the filter is waited and controled filling the following bag.		×	
When the bottom bag is full, it is turned over again.		×	
It is hung again.		×	
The bag is controled and waited for filling.		×	
Filtered erythrocyte bag is removed from the hanger.	×		
The excess hose of the filtered erythrocyte bag is cut off and the cut parts are sterilized with machine.		×	
Unnecessary hose parts are torn off.	×		
Unnecessary hose parts are thrown away.	×		
The product is held for labeling process.		×	
5.Platelet Separation			

Table 2. continues

Rested buffy coat bags are placed in centrifuge baffles.		×	
The baffles are balanced by weighing on the scales.		×	
The balanced baffles are placed in a refrigerated centrifuge.		×	
Inner cover of the centrifuge machine is closed.		×	
Outer cover of the centrifuge machine is closed.		×	
The appropriate test program is selected in the centrifuge.			×
The device is started.			×
The operation of the device is followed.			×
Outer cover of the centrifuge machine is opened.		×	
Inner cover of the centrifuge machine is opened.		×	
Centrifuged buffy coat bags are taken from the centrifuge machine.		×	
Buffy coat bags are placed in the extractor.		×	
The test program is selected in the extractor.			×
The clamps of the buffy coat bags placed in the extractor are broken.	×		
The platelets are removed from the extractor.		×	
6.Labeling of Products			
The excess hoses of the bags experienced product separation process are cut off and the cut parts are sterilized with machine.	×		
Unnecessary hose parts are torn off.	×		
Unnecessary hose parts are thrown away.	×		
The grazing process is done to the hose in erythrocyte bag.	×		
The liquid coming from the hose is mixed in the bag by shaking.	×		
The related pages are opened on the computer screen.			×
Barcode on the bag is read via reader.		×	
The label output of the product is taken.		×	
The labels is read via reader again.		×	
Labels are affixed onto the bags.		×	
The required sample tube is found from the tube rack.		×	
Sample tubes are attached to the erythrocyte bag.	×		
Erythrocytes are stored in +4°C cabinet.		×	

Table 2. continues

Thrombocytes are kept at room temperature in 20-24°C agitators (platelet storage cabinet) for a maximum of 5 days.		×	
Plasmas are stored in deep freeze.		×	
7. Plasma shocking process			
Plasmas are taken from the cabinet.		×	
They are inserted into the shocking device.		×	
The device is started.			×
Plasmas are removed from the device.		×	
Plasmas are stored in deep freeze.		×	
8. Thrombocyte pooling			
The desired number of random platelets are removed from the agitator.		×	
Random platelets are combined in the sterile connecting device.		×	
The pooled platelet is suspended.		×	
On the pooled platelet bag, the conformity label(blood group, expiration date etc.) of the combined random platelets is affixed.		×	
Filtered platelet bag is removed from the hanger.		×	
Thrombocytes are kept at room temperature in 20-24°C agitators(platelet storage cabinet) for a maximum of 5 days.		×	
9. Infection Test			
	×		
The tube is placed in the centrifuge machine.			×
Test program is selected and the device is operated.			×
The operation of the device is followed.			×
The centrifuged tube is removed from the centrifuge machine.	×		
The label on the tube is read through the label reader.	×		
The tube is inserted into the autoanalyzer.		×	
The device is run in the appropriate program.			×
The operation of the device is followed.			×
The sample tubes are taken from the autoanalyzer.	×		
The results are checked from the computer.			×
The tubes are waited to receive the witness sample.	×		
10. Witness sample separation			

Table 2. continues

The barcodes of the infection test samples are turned in the same direction.	×		
The barcodes of the infection test samples from the autoanalyzer are read and appropriate labels are collected.	×		
The empty witness sample tube taken from drawer.	×		
The empty witness sample tube is placed on the rack where the infection test samples are.	×		
Blood sample is drawn by pipette from infection test samples and filled into witness sample tubes.	×		
Labels of witness sample tubes are affixed.	×		
The covers of the witness sample tube are closed.	×		
Witness sample tube is stored.		×	
Infection test samples are discarded.	×		
11. Loading distile water to the autoanalyzer			
The disinfectant liquid is removed from the cabinet.		×	
Required amount of this liquid is poured into the distile water bin.		×	
The bin is moved to the autoanalyzer.		×	
The bin is connected to the autoanalyzer with hose.		×	
After the filling process, the bin is reinserted into the distile water device.		×	
12.Placement of the solutions required for the operation of the autoanalyzer			
The outer cover of the autoanalyzer are opened.		×	
Inner covers of the autoanalyzer are opened.		×	
Empty solution bottles are removed from the autoanalyzer.		×	
The lids of the full bottles are opened.		×	
The plugs are attached to the bottle openings.		×	
The bottles are placed in the respective cells of the machine.		×	
The outer cover of the autoanalyzer are closed.		×	
Inner covers of the autoanalyzer are closed.		×	
The liquid levels within the control tubes are checked.		×	
Control liquid is filled into the control tubes.		×	
The control tubes are placed in the autoanalyzer.		×	
It is checked on the screen that the device is working properly.			×
13. Tube Centrifuge in the Microcentrifuge			

Table 2. continues

The tube is placed in the centrifuge machine.	×		
Test program is selected and the device is operated.			×
The operation of the device is followed.			×
The centrifuged tube is removed from the centrifuge machine.	×		
14. Erythrocyte reservation			
The patient's blood samples are taken.		×	
The label on the tube is read to see what the doctor wants.		×	
The sample tube of the desired product is removed from the cabinet.		×	
The tubes are placed in the centrifuge machine.	×		
Test program is selected and the device is operated in the centrifuge machine.			×
The operation of the device is followed.			×
The centrifuged tube is removed from the centrifuge machine.	×		
The tubes are placed in the plastic tube rack by bringing barcodes on the tube forward.	×		
The tube rack is placed in the cross match machine.	×		
The device is run in the appropriate program.		×	
The operation of the device is followed.		×	
The tube rack is taken from the device.	×		
The lid of each tube is closed.	×		
If the cross match test results are acceptable, the reserve label is printed on the product.		×	
The relevant tubes are attached to the erythrocyte bag.	×		
The product is removed with the tube in the reservation cabinet.		×	
15. Blood Group Identification Process			
The tube is placed in the centrifuge machine.	×		
Test program is selected and the device is operated.			×
The operation of the device is followed.			×
The centrifuged tube is removed from the centrifuge machine.	×		
The tubes are placed in the plastic tube rack by bringing barcodes on the tube forward.	×		
The tube rack is placed in the blood group determination device.	×		
The device is run in the appropriate program.		×	

Table 2. continues

The operation of the device is followed.		×	
The tube rack is taken from the device.	×		
The lid of each tube is closed.	×		
The label of the result is printed for products.		×	
Stored.		×	
16. Discharge of waste water from cross match and blood group machine			
The waste water bin is removed from the site.	×		
The bin is moved to the sink.	×		
The lid is opened.	×		
The waste water is poured into the sink.	×		
The lid is closed.	×		
The bin is moved to its place and placed.		×	
17. Gel card centrifuge			
The gel cards are placed in the centrifuge.		×	
The appropriate test program is selected in the centrifuge.			×
The device is started.			×
The operation of the device is followed.			×
The gel cards are removed from the device and cards are placed in the box after the device is stopped.		×	
Cards are kept for use in blood group and cross machine.		×	
18. Manual filling of gel cards for blood group and cross match machine operations.			
The erythrocyte dilution solution is filled into a tube.		×	
The solution is taken from the tube by injector.		×	
The small cells in the gel cards are filled from the dilution solution in the injector.		×	
Sample of the centrifuged blood tube to be processed is drawn by injector.	×		
Blood sample is squeezed into gel cards.	×		
Gel cards are placed in incubator.	×		
The device is started.			×
The operation of the device is followed.			×
Cards are removed from incubator.	×		
Gel cards set in centrifuge.	×		
The appropriate test program is selected in the centrifuge.			×
The device is started.			×

Table 2. continues

The operation of the device is followed.			×
Cards are removed from the device.	×		
Cards is put into the cross or blood group machine.	×		
19. Preparing cross and blood group machines for operating.			
Centrifuged gel cards are placed in the machine.		×	
The machine's cover is opened.		×	
The required liquids (erythrocyte dilution solution, blood group screening cells etc.) are filled into the relevant locations on the machine.		×	
The trash box of the machine is emptied.		×	
The machine's cover is closed.		×	
Things loaded in the machine is introduced to the computer.		×	
20. Plasma and thrombocyte reservation			
The desired products for the patients are checked from the computer screen.		×	
The desired product is taken out of the closet.		×	
The product is booked from the system on behalf of the patient.		×	
The patient reserve label is affixed to the product.		×	
Products are removed in reserve cabinet.		×	
21. Removal of reservations for products that expire at the end of the reservation.			
The list of products that need to be booked down is looked at from the screen.		×	
That product is removed from the reservation cabinet.		×	
Barcode is read and removed from the system.		×	
Reserved label is removed.		×	
The product is put into the stock cabinet.		×	
22. Blood irradiation technique			
The blood products to be irradiated are removed from the cabinets.		×	
Products are transported to the ray room.		×	
The irradiated products are moved to the lab.		×	
The irradiated product labels are adhered to the irradiated products.		×	

Table 3. REBA scores all the sub-work steps

Sub-Tasks	REBA Result	Scoring
1.Taking Samples from Whole Blood Bag		
1	9	high risk
2	6	medium risk
3	8	high risk
4	8	high risk
5	9	high risk
6	7	medium risk
7	4	medium risk
8	4	medium risk
9	4	medium risk
10	7	medium risk
11	9	high risk
2.Centrifugation of Whole Blood Bags		
1	10	high risk
2	10	high risk
3	5	medium risk
4	10	high risk
5	7	medium risk
6	10	high risk
7	1	negligible risk
8	1	negligible risk
9	1	negligible risk
10	10	high risk
11	7	medium risk
12	10	high risk
3.Erythrocyte and Plasma Separation		
1	6	medium risk

Table 3. continues

2	7	medium risk
3	3	low risk
4	3	low risk
5	7	medium risk
6	4	medium risk
7	7	medium risk
8	5	medium risk
9	7	medium risk
10	3	low risk
11	7	medium risk
4. Removal of Filtered Erythrocytes		
1	8	high risk
2	7	medium risk
3	8	high risk
4	8	high risk
5	7	medium risk
6	8	high risk
7	8	high risk
8	7	medium risk
9	9	high risk
10	4	medium risk
5. Platelet Separation		
1	10	high risk
2	5	medium risk
3	10	high risk
4	7	medium risk
5	10	high risk
6	1	negligible risk
7	1	negligible risk
8	1	negligible risk
9	10	high risk
10	7	medium risk

Table 3. continues

11	10	high risk
12	7	medium risk
13	3	low risk
14	3	low risk
15	7	medium risk
6.Labeling of Products		
1	8	high risk
2	7	medium risk
3	9	high risk
4	8	high risk
5	9	high risk
6	2	low risk
7	10	high risk
8	6	medium risk
9	10	high risk
10	6	medium risk
11	10	high risk
12	5	medium risk
13	11	very high risk
14	10	high risk
15	12	very high risk
7.Plasma shocking process		
1	11	very high risk
2	11	very high risk
3	3	low risk
4	11	very high risk
5	12	very high risk
8.Thrombocyte pooling		
1	10	high risk
2	7	medium risk
3	8	high risk
4	7	medium risk
5	8	high risk
6	10	high risk

Table 3. continues

9. Infection Test		
1	8	high risk
2	2	low risk
3	1	negligible risk
4	8	high risk
5	4	medium risk
6	8	high risk
7	3	low risk
8	3	low risk
9	8	high risk
10	3	low risk
11	5	medium risk
10. Witness sample separation		
1	7	medium risk
2	4	medium risk
3	9	high risk
4	4	medium risk
5	4	medium risk
6	8	high risk
7	4	medium risk
8	9	high risk
9	9	high risk
11. Loading distile water to the autoanalyzer		
1	7	medium risk
2	7	medium risk
3	8	high risk
4	11	very high risk
5	7	medium risk
12.Placement of the solutions required for the operation of the autoanalyzer		
1	7	medium risk
2	5	medium risk
3	9	high risk
4	6	medium risk
5	6	medium risk

Table 3. continues

6	9	high risk
7	7	medium risk
8	5	medium risk
9	8	high risk
10	6	medium risk
11	8	high risk
12	3	low risk
13. Tube Centrifuge in the Microcentrifuge		
1	8	high risk
2	3	low risk
3	1	negligible risk
4	8	high risk
14. Erythrocyte reservation		
1	6	medium risk
2	5	medium risk
3	11	very high risk
4	8	high risk
5	2	low risk
6	1	negligible risk
7	8	high risk
9	7	medium risk
10	2	low risk
11	5	medium risk
12	5	medium risk
13	2	low risk
14	6	medium risk
15	5	medium risk
16	5	medium risk
17	11	very high risk
15. Blood Group Identification Process		
1	8	high risk
2	2	low risk
3	1	negligible risk
4	8	high risk

Table 3. continues

6	7	medium risk
7	2	low risk
8	5	medium risk
9	5	medium risk
10	2	low risk
11	6	medium risk
12	6	medium risk
13	9	high risk
16. Discharge of waste water from cross match and blood group machine		
1	10	high risk
2	6	medium risk
3	9	high risk
4	9	high risk
5	9	high risk
6	9	high risk
17. Gel card centrifuge		
1	5	medium risk
2	3	low risk
3	3	low risk
4	1	negligible risk
5	5	medium risk
6	4	medium risk
18. Manual filling of gel cards for blood group and cross match machine operations.		
1	5	medium risk
2	6	medium risk
3	5	medium risk
4	6	medium risk
5	5	medium risk
6	5	medium risk
7	2	low risk
8	1	negligible risk

Table 3. continues

9	5	medium risk
10	5	medium risk
11	3	low risk
12	3	low risk
13	1	negligible risk
14	5	medium risk

15	7	medium risk
19. Preparing cross and blood group machines for operating.		
1	7	medium risk
2	7	medium risk
3	8	high risk
4	8	high risk
5	7	medium risk
6	5	medium risk
20. Plasma and thrombocyte reservation	329	5.393442623
1	8	high risk
2	12	very high risk
3	8	high risk
4	5	medium risk
5	12	very high risk
21. Removal of reservations for products that expire at the end of the reservation.		
1	8	high risk
2	12	very high risk
3	8	high risk
4	5	medium risk
5	12	very high risk
22. Blood irradiation technique		
1	11	very high risk
2	4	medium risk
3	4	medium risk
4	5	medium risk