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EFFECT OF THE RISK ARISING FROM WORKING POSTURES ON MENTAL WORKLOAD: AN EXPERIMENTAL STUDY

M.Sc. Thesis by

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EFFECT OF THE RISK ARISING FROM WORKING POSTURES ON MENTAL WORKLOAD: AN EXPERIMENTAL STUDY

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M.Sc. THESIS EXAMINATION RESULT FORM

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EFFECT OF THE RISK ARISING FROM WORKING POSTURES ON MENTAL WORKLOAD: AN EXPERIMENTAL STUDY

ABSTRACT

As the workload of the employees increase, the performance of the worker decreases, their capacity decrease, the inability to complete the task on time and the number of errors increase. In order to protect employees from these undesirable effects, it is important to measure the mental workload level of workers. In this thesis, the hypothesis that poor work postures, lifting, incorrect holding and carrying actions in the workplace affects the mental workload of the employees was proposed. In order to obtain the proposed hypothesis data, 84 operators were selected from an integrated meat-dairy food facility in Konya and their operations were analyzed with ergonomic risk assessment methods REBA, RULA and NIOSH lifting equation methods. In addition, using the data of the surveys conducted with these 84 operators, the mental workload value of each worker was obtained with NASA TLX workload measurement method. For the purpose of the study, the relationship between the changes in the mental load levels found by NASA TLX method and the changes in risk levels found by REBA, RULA and NIOSH Lifting Equation methods was investigated with multiple regression analysis which is an analysis method that provides the cause-effect relationship between the variables. As a result of the study, it was found that the increments in the difficulties of the body postures covering the whole body of the employees increase the mental workload level of the employees. In addition, increases and decreases in the risk levels of lifting or lowering tasks have been shown to affect the mental workload of the employee.

Keywords: Ergonomics, mental workload, risk assessment methods, reba, rula, niosh, nasa tlx.

ÇALIŞMA DURUŞLARINDAN KAYNAKLANAN RİSKLERİN ZİHİNSEL İŞ YÜKÜ ÜZERİNE ETKİSİ: BİR ALAN ÇALIŞMASI

ÖZ

Çalışanın iş yükü arttıkça, işçilerin performansı ve çalışma kapasiteleri düşer, verilen işi zamanında tamamlayamama sayısı ve hata sayısı artar. Çalışanları iş yükünün getirdiği bu olumsuz etkilerden korumak için zihinsel iş yükününün ölçülmesi önemlidir. Bu çalışmada, işyerinde uygun olmayan çalışma duruşu, kaldırma, yanlış tutma ve taşıma eylemlerinin çalışanların zihinsel iş yükünü etkilediği hipotezi ortaya atılmıştır. Önerilen hipotez verilerini elde etmek için Konya'da bir gıda şirketinden seçilen 84 operatör ve yaptıkları 84 iş ergonomik risk değerlendirme yöntemleri REBA, RULA ve NIOSH kaldırma denklemi yöntemleri ile analiz edilmiştir. Ayrıca, bu 84 operatörle yapılan anketlerin verileri kullanılarak, her bir işçinin zihinsel iş yükü değeri NASA TLX iş yükü ölçüm yöntemi ile elde edilmiştir. Çalışmanın amacı doğrultusunda, NASA TLX yöntemi ile bulunan zihinsel iş yükü düzeyleri ile REBA, RULA ve NIOSH kaldırma denklemi yöntemlerinde bulunan risk düzeyleri arasındaki ilişki değişkenler arasındaki neden sonuç ilişkisini belirten çoklu regresyon analizi ile araştırılmıştır. Bu tez çalışması sonucunda, çalışanların tüm vücudunu kapsayan vücut duruşlarının risk seviyelerindeki artış, çalışanların zihinsel iş yükü düzeyini artırmaktadır. Ek olarak, kaldırma veya indirme görevlerinin risk seviyelerindeki artış ve düşüşlerin, çalışanın zihinsel iş yükünü etkilediği sonucuna varılmıştır.

Anahtar Kelimeler: Ergonomi, zihinsel iş yükü, risk değerlendirme yöntemleri, reba, rula, niosh, nasa tlx.

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ABBREVATIONS

CATIA	Computer Aided Three-Dimensional Interactive Application
IEA	International Energy Agency
JSI	Job Strain Index
LI	Lifting Index
MANTRA	Manuel Tasks Risk Assessment Tool
MD	Musculoskeletal disorders
NASA RTLX	The National Aeronautics and Space Administration–Raw Task Load Index
NASA-TLX	The National Aeronautics and Space. Administration–Task Load Index
NIOSH	National Institute of Occupational Safety and Health
NLE	NIOSH Lifting Equation
OWAS	Ovako Working Posture Analysis System
QEC	Quick Exposure Check
REBA	Rapid Entire Body Assessment
RULA	Rapid Upper Limb Assessment
SPSS	Statistical Package for the Social Sciences
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
WMD	Work-Related Musculoskeletal Disorders
SMAA-2	Stochastic Multi-Criteria Acceptability Analysis-2
RWL	Recommended Weigh Limit

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CHAPTER 1

INTRODUCTION

Prior to the industrial revolution, there was an understanding that regarded human being as a machine or a production component. Human beings were just perceived as an object used to sustain production. In conjunction with the developments in the industry, perspectives to the human being starting to change positively and human health in physical and psychological terms has gained importance for more efficient production. As a result of this, the human environment, equipment used by the people and psychological and physiological effects have led to the emergence of the human factors science.

Ergonomics is a discipline that takes into consideration the relations between individuals and other elements in the system and applies theories, principles, data and methods in design in order to optimize human health, safety and performance of the system. Factors such as performing heavy load lifting, carrying, pushing or pulling works that are frequently repeated, and repeating the same task for a long time, performing work that require speed will lead to various occupational diseases of the employees. The design of the work and the equipment used in the workplaces according to the ergonomics principles ensures that the negativities that may be experienced are prevented. Within the scope of ergonomics, one of the most common occupational diseases in workers is musculoskeletal diseases.

Musculoskeletal disorders (MD) that appear in employees, which may be allied to work-related pain, movement restriction and disability, affecting soft tissues such as muscles, tendons, ligaments, and discs, are considered as work-related musculoskeletal disorders [5]. In order to prevent work-related musculoskeletal diseases and their effects, it is important to identify and evaluate ergonomic risks in the workplace. The work posture, defined as the alignment of the head, body, arms and legs according to the work performed and the characteristics of the work, has a very important role in the emergence of work-related musculoskeletal disorders (WMD). In

work environments where ergonomic risk assessment methods are applied on working postures, employees gain the opportunity to move and access to the parts and tools and equipment easily, thus reducing the physical strain and the risk of WMD. There are many methods used to determine the risk levels of work postures exhibited in the work environment. Examples include OWAS (Ovako Working Posture Analysis System), RULA (Rapid Upper Limb Assessment), REBA (Rapid Entire Body Assessment), JSI (Job Strain Index) methods [6].

In addition to poor working postures, lifting, holding and carrying actions in the workplaces cause the employees to get tired and to be forced to be can lead to quick health problems related to the occupational health problems. The ergonomic risks of the employees during lifting and transportation can be determined by the NIOSH lifting equation method [7].

The lack of ergonomically appropriate working postures causes the employee to have difficulty in performing his / her job and this increases the perceived workload level by the employee. Accordingly, it is important to systematically determine and control the working postures and perceived workload level and to improve risk-containing situations for increasing production and labor productivity. In order to measure the effect of work postures on workload level, the mental workload levels of workers were calculated by NASA Task Load Index-NASA TLX, Subjective Workload Assessment Technique-(SWAT), NASA Bipolar Rating Scale,Cooper-Harper Rating Scale, Bedford Scale, Zwer Ebenen Intensitats-Scale methods.

Mental workload is the level of psychological impact of the employee, which affects negatively the performance and reactions of the employees and which occurs with the pressures in the work and work environment. Mental workload can be affected by many factors. It may be affected by factors such as difficulties in work, stress, pressure, appreciation and reward systems, production speed, mobbing that the employee encounters in the work environment.

In the study, in addition to work, stress, pressure, appreciation and reward systems, production speed, mobbing etc., it has been hypothesized that lifting, holding and carrying actions can affect mental workload. Work posture defines the movements

performed by body parts such as arms, legs and trunk to perform the task that the employee is responsible for. There is a limit of movement of the body limbs while the employee is doing the job in which he/she is responsible for. If the employee exceeds the body limits with repetitive tasks, heavy loads, etc., dangerous work postures occur and musculoskeletal diseases begin to develop.

In the study, the workers who are work in the food factory were analyzed. REBA, RULA and NIOSH methods for determination of ergonomic risk levels, NASA TLX method for determination of mental load levels were used in the analysis. REBA, RULA and NIOSH methods have been used to determine the risk levels of operations associated with working postures, lifting and handling as a result of the inspection of the video recordings taken during production in the factory. Furthermore, based on the questionnaires conducted with the workers who are working in the factory, the workload levels of the employees were determined by NASA TLX method.

Finally, the relationship between the changes in the mental load levels found by NASA TLX method due to the change in risk levels found in REBA, RULA and NIOSH Lifting Equation methods was investigated with multiple regression analysis for the cause-effect relationship between the variables.

The study consists of five chapters. The first part is the introduction and the ergonomics, working postures and mental workload and the purpose of the study were mentioned.

In the second part, the studies in the literature were mentioned. These studies were explained in two separate sections as REBA, RULA and NIOSH methods which are ergonomic risk assessment methods and NASA TLX method which is a mental workload measurement.

In the third chapter, the definition of ergonomics and the types of ergonomics were discussed. Moreover, ergonomic risk assessment methods, work-related musculoskeletal diseases, mental workload and NASA TLX method are mentioned.

In the fourth chapter, the integrated meat-dairy food facility where the study is carried out were introduced and the applications of REBA, RULA, NIOSH and NASA TLX

methods to the employees were shown. Also, information was given about the regression analysis and the Ergofellow program used in the analysis.

In the fifth chapter, the results were interpreted and future studies are discussed.

CHAPTER 2

LITERATURE REVIEW

In this section, studies on REBA, RULA, NIOSH and NASA TLX methods are summarized in two sections under the titles of work postures and mental workload.

2.1. Working Postures

Ali A. & Qutubuddin S. (2012) have found that in India's saw mills, all conditions that exposed workers to MSD risks may be due to manual workload. Therefore, they aimed to find the exact risk levels by examining these works with REBA and RULA methods [8].

Sahu S., et al. (2013) studied potters and sculptors and examined their inappropriate positions with REBA and RULA methods in their study. The analysis showed that some body postures were detrimental to subjects and that there were deep deviations from the natural curvature of various body parts due to strange body postures [9].

Kim T., (2014) have studied the radiological technology specialists who have been working in hospitals for more than 5 years. They made measurements with the methods of REBA, RULA and OWAS and determined which postures should be developed [10].

Coskun M., et al. (2015) analyzed 10 workstations in a compressor plant using the NIOSH method to determine their risk levels. In line with the risk levels, the necessary improvement activities for the stations requiring improvement were presented to the senior management of the company [11].

Thetkathuek A., et al. (2016) surveyed workers in the frozen food industry who had musculoskeletal disorders. Based on these questionnaires, the risk assessment was performed with REBA and RULA methods [12].

Fazi M., et al. (2017) aimed to reduce employee absenteeism due to posture problems in a Small and Medium Enterprises (SME) food production company in the Klang

Valley of Malaysia. For this purpose, the risk levels to which the workers were exposed were determined using REBA and RULA methods [13].

Boulila A. et al. (2018) investigated the REBA and RULA methods in 3 workstations: milling, turning and drilling for 4 machining operations and 12 operator stops that directly affected the performance of all machining stations in the production of molds. As a result of the study, it was found out that the workstations were not ergonomic and the operators did not follow the ergonomic rules, and ideas for improving the working environment were visualized with the CATIA drawing program and proposed [14].

Rizkya I., et al. (2018) employed small- medium industries that produced food in North Sumatra. The results of questionnaire forms related to musculoskeletal diseases of the employees and risk assessment were performed by using REBA method [15].

Yadi H., et al. (2018) conducted an ergonomic assessment directly at a workstation in the area of a suspending agent by using the RULA / REBA methods. Simulations were performed using CATIA software to evaluate the designs of a conveyor, an adjustable table and the overall operating method [16].

Kathiravan S., & Gunarani I. (2018)'s study covers the analysis of primary housing works such as manual material handling, masonry and plaster works with REBA, RULA posture analysis methods and surveys. The data obtained were used to determine the level of ergonomic risks the construction workers were exposed to in the residential area. The results of the questionnaires and posture analysis methods were examined together [17].

Cremasco M, et al. (2019) examined the postural attitudes of the employees in the interaction with the workstation elements and the working environment in relation to manual wood chippers in the forestry sector using the RULA and REBA risk assessment methods. They compared the results of REBA and RULA methods according to their findings. As a result, they found that RULA was a more effective method [18].

Julianus H. (2019) used REBA on a stage of carrying sack and RULA on a stage of lifting sack to analyze the working posture for rice millers. A high level of risk was found during sack lifting and sack transport, and it was determined that changes in the work were required [19].

Kulkarnia S. and Devalkarb V. (2019) investigated the degree of risk of the construction industry using the REBA and RULA methods. According to the level of risks, corrective measures were suggested for every task having a high risk factor [20].

Nagaraj T., & Jeyapaul R. (2019) have applied REBA method to the workers who were standing in the sewing factory during full working hours with highly repetitive processes. According to REBA score workers' postures were at medium, high and very high-risk levels and had to be eliminated necessarily [21].

Mahmood S., & Aziz A. (2019) studied the poultry feed manufacturing industry in order to determine the risks of employees related to work posture problems and to propose standardization. Posture analysis evaluations of RULA and REBA methods were applied to analyze the working stance of workers. In addition, it was thought that with this research, the employees became aware of their working postures [22].

Manjunath K. (2019) conducted the study to reduce the work related musculoskeletal disorders of workers in the garment industry. Improvements were proposed in line with REBA, RULA, NIOSH Lifting Equation and Rodger's Fatigue Model measurements [23].

2.2. Mental Workload

Rubio S.,et al.(2004) divided 36 volunteer students at Madrid Complutense University into three equal groups, applying NASA TLX to one group, SWAT to the second group, and Work Load Profile to the last group. The subjects repeated the given tasks in the same order and in single and double cases. The subjects were given equal time to complete the work and as soon as they completed their tasks, they were surveyed. For each instrument (TLX, SWAT, and WP), ANOVA was performed in performance measurements to check for the presence of performance differences related to the workload assessment method [24].

Yurko Y., et al. (2010) evaluated the impact of workload on performance during simulator training on a complex laparoscopic task. They conducted three separate trials on 28 subjects who followed the same curriculum on the fundamentals of laparoscopic surgery suturing model, and tested in the animal operating room (OR) on a Nissen fundoplication model after training. During the test, they analyzed the performances using the NASA TLX scale [25].

Yiyuan Z. (2011) focused on the possibility that the mental workload calculated with NASA TLX can be used in aircraft design stage. In this study, the NASA-TLX questionnaire was completed by a team of six experts and evaluated by 2 pilots. This experiment confirmed the application of human factors at the design stage using NASA-TLX [26].

Gülkaç H., (2013) divided the pilots working in a private airline into two 3 groups firstly according to their experience and secondly according to their age. The mental workloads of these groups in educational simulators were measured and compared with each other [27].

Seker A., (2014) applied the NASA TLX method to assess the effects of demographic factor level on mental workload of experts working in basic stages of R&D projects evaluation activities in a public institution. Statistical analyses was performed with 6 scales in NASA-TLX method and an executive expert was chosen by using AHP

(Analytic Hierarchy Process) and TOPSIS (Technique of Order Preference Similar to Ideal Solutions) methods [28].

Karadağ M., & Cankul I. (2015) assessed the mental workload of 171 nurses using the NASA TLX scale developed by Hart and Staveland as a data collection tool. The variables such as age, marital status, number of children, working section, total working time in the profession, working time in the hospital, number of witnesses, status and shifts, educational status, general satisfaction with the profession and number of patients were taken into consideration. The effect of these variables on nurses' mental loads were examined [29].

Delice E. (2016) carried out her work in the emergency room of three hospitals. In cases where the patient density was high, it was observed that the mental workload of physicians increase and it affect their performances. As a result of this observation, the workload levels of the physicians were measured NASA RTLX method which didn't use binary comparisons while calculation. Finally, the results have been interpreted with frequency analysis, t test and ANOVA test [30].

Rahman N. et al. (2017), his study aimed to determine the complexity effects of the driving situation by assessing the mental workload of the drivers in real time. The driving settings were divided into 3 sessions, simple, complex and very complex, and after each experimental driving driver session, drivers were administered a NASA TLX survey. According to NASA-TLX results, the sessions were ranked according to their effects on mental workload [31].

Delice E., (2018) proposed an integrated approach based on NASA TLX and SMAA-2. The box letter manufacturing process were used as a case study. In this case study, NASA-TLX & SMAA-2 combined method are used for three different problems in terms of mental workload. As a result of the study, it was found that combined NASA-TLX and SMAA-2 approach gave more accurate results compared to NASA-TLX method [32].

Emec S.,& Akkaya G. (2018) aimed to prove that weights can be calculated by AHP while calculating the mental workload with the NASA-TLX method. For this purpose,

they used the physicians in a hospital as subjects in order to implement their studies. After the implementation, factor weights were calculated by AHP method and mental workload was calculated by NASA TLX measurement method and the results were compared [33].

As a result of the literature research, it is seen that many risk level assessment methods and mental workload measurement methods are applied in different sectors. However, the studies below have integrated mental and physical workload.

Dağdeviren M., et al. (2005) developed the method which determined the total workload of the employees with the AAP method, taking into account mental factors, physical factors, environmental factors and positional factors [34].

Ekinci E., & , Can G. (2018) assessed the perceived workload and working postures to evaluate the ergonomic risk levels of operators with a multi criteria decision making approach. They have used REBA and NASA-TLX scales for this evaluation [35].

Yener Y., & Can G. (2019) aimed to develop a new appointment system for workers to work in appropriate jobs in order to increase the volume of production and reduce the level of physical and mental fatigue. In order to determine which jobs the workers should be assigned, they measured the mental and physical workload of the employees by using Nasa TLX and REBA methods. They used these measurements in the work rotation they created [36].

Table 2.1. Literature Review

Researcher	The Subject of Ergonomics	Method	Experimental Area
Rubio S.,et al.(2004)	Mental Workload	NASA TLX&SWAT	University
Dağdeviren M., et al. (2005)	Integrated Approach	AAP	Manufacturing
Yurko Y., et al. (2010)	Mental Workload	NASA TLX	Aviation industry
Yiyuan Z. (2011)	Mental Workload	NASA TLX	Aircraft design
Ali A. & Qutubuddin S. (2012)	Risk Assessment	REBA&RULA	Saw mills
Gülkaç H., (2013)	Mental Workload	NASA TLX	Aviation industry
Sahu S., et al. (2013)	Risk Assessment	REBA&RULA	Pottery and sculptor
Seker A., (2014)	Mental Workload	NASA TLX	Public institution
Kim T., (2014)	Risk Assessment	REBA&RULA&OWAS	Hospital
Karadağ M., & Cankul I. (2015)	Mental Workload	NASA TLX	Hospital
Coskun M., et al. (2015)	Risk Assessment	NIOSH	compressor plant
Delice E. (2016)	Mental Workload	NASA RTLX	Hospital
Thetkathuek A., et al. (2016)	Risk Assessment	REBA&RULA	Frozen food industry
Fazi M., et al. (2017)	Risk Assessment	REBA&RULA	Food production
Rahman N. et al. (2017)	Mental Workload	NASA TLX	Drivers
Delice E., (2018)	Mental Workload	NASA-TLX & SMAA-2	Manufacturing
Boulila A. et al. (2018)	Risk Assessment	REBA&RULA	Manufacturing
Rizkya I., et al. (2018)	Risk Assessment	REBA	Food production
Yadi H., et al. (2018)	Risk Assessment	REBA&RULA	Chemical industry

Table 2.1. Literature Review (Continued)

Kathiravan S., & Gunarani I. (2018)	Risk Assessment	REBA&RULA	Housework
Emec S.,& Akkaya G. (2018)	Mental Workload	NASA TLX	Hospital
Ekinci E., & , Can G. (2018)	Integrated Approach	REBA&NASA TLX	Manufacturing
Cremasco M, et al. (2019)	Risk Assessment	REBA&RULA	Forestry sector
Julianus H. (2019)	Risk Assessment	REBA&RULA	Rice miller
Kulkarnia S. and Devalkarb V. (2019)	Risk Assessment	REBA&RULA	Construction industry
Nagaraj T., & Jeyapaul R. (2019)	Risk Assessment	REBA	Sewing factory
Mahmood S., & Aziz A. (2019)	Risk Assessment	REBA&RULA	Poultry feed manufacturing
Manjunath K. (2019)	Risk Assessment	REBA&RULA&NIOSH	Garment industry
Yener Y., & Can G. (2019)	Integrated Approach	NASA TLX &REBA	Manufacturing

As can be seen from Table 2.1, in the literature, there have been many studies related to ergonomic risk assessment methods REBA, RULA and NIOSH and mental workload. As a result of the integrated studies on the employees' working postures and mental workloads, the total risk level was tried to be achieved. However, it was noticed there is a gap in literature on the subject of whether working postures affect mental workload.

CHAPTER 3

THEORETICAL FRAMEWORK

3.1. Definition of Ergonomics

Ergonomics derives from two Greek words: ergon, meaning work, and nomos, meaning natural laws. Combined they create a word that means the science of work and a person's relationship to that work. The International Ergonomics Association (IEA) defines ergonomics as; the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance [37]. The science of ergonomics ensures the harmony of the operator, workplace and the work. When the expectation from the job is adapted to human beings, human productivity increases. Ergonomics is a science that exposes information about human behavior, ability, boundary, and all features and applies this information to vehicles, machines, systems, and works in the environment. Since ergonomics is a multidisciplinary discipline, it includes physicians in relation to human health, engineers in relation to machine design, and economists in relation to cost [38]. Because of this diversity ergonomists use methods and data of many different disciplines such as body size, body shape, muscle, force, noise, heat, vibration, endurance, hearing, joint, skill, communication, behavior, emotion, vision, light [3].

3.2. Types of Ergonomics

According to IEA, ergonomics is divided into three groups; Physical Ergonomics, Cognitive Ergonomics, Organizational Ergonomics. Physical ergonomics deals with; physical environment design (noise, vibration, lighting, heating, ventilation, chemicals), health and safety design (risk of injury and control, manual transport, protective equipment), performance modeling, examination of body position, reach distance (arms, hands, legs, foot), engineering anthropometry, examination of human in robotic systems, designing in front of display. Cognitive Ergonomics related to employee participation, technology management and organizational change, job programming, performance modeling, total quality management, socio-technical organization design, project management, management change, computer assisted management, human element in care, directives and standards, participatory ergonomics, macro ergonomics. Organizational Ergonomics is concern with human mistake, design and use of information systems, design of indicators, ability to acquire and protect winners, staff education, decision support staff, intelligent systems, performance modeling, classification of analyses, testing and inspection, human power planning and programming, mental stress and overload.

Although ergonomics is applicable for places where human work such as industrial workplaces, agricultural enterprises, offices, schools, hospitals, hotels, and houses, it is mostly used for worker. New danger and risk groups arise with the increase in occupational accidents and occupational diseases that employees are exposed to due to industrialization. These problems are not given too much importance is preventing businesses to operate in a safe manner. When evaluated in terms of both the company and the employees, there are financial and moral losses because of these danger and risk groups [39]. When the health and safety of person40s working in the company is taken into consideration by the employer, workers do not experience fatigue and discomfort, have high morale and job participation increase. Also workers working in the company which attach importance to human factors, produce better quality products. As a result, unnecessary costs from workers are reduced through human factors applications.

3.2.1. Physical Ergonomics

Physical Ergonomics deals with the anatomical, anthropometric, physiological and biomechanical characteristics of humans in relation to their physical activity. Work postures, material management, repetitive movements, work-related musculoskeletal disorders, workplace design, safety and health are issues of physical ergonomics. Physical ergonomics is the most researched topic in order to ensure the comfort of employees and increase their satisfaction levels. For example, for office design, table chairs, keyboards and computers should be adjusted to suit the employee's body size. Work is also carried out on tools used by employees in difficult work areas such as construction and production [40].

3.2.2. Cognitive Ergonomics

Cognitive ergonomics works on the ability to process information and interact with data. It examines mental processes such as attention, perception, repetition, grouping, coding, and memory in an integrated way with the science of psychology. It is used extensively in the design of controls, control buttons, signals, joysticks, steering and vehicle-aircraft displays [41].

3.2.3. Organizational Ergonomics

Organizational ergonomics aims to optimize the organizational structures of workplaces and sociotechnical systems through policies and processes. Communication, team resource management, work design, working hours, teamwork, participatory design, community ergonomics, harmonious work, collaborative work, new business paradigms, organizational culture, virtual organizations, telework, and quality management are among the topics of organizational ergonomics. Organizational ergonomics tries to organize human and work in the best possible way [42].

3.3. Ergonomic Risk Assessment Methods

Risk is the result of a harmful event that may occur and the probability of its occurrence. It is described in a wide range, from a very minor incident to a disaster-level accident. Employees may be exposed to many risk factors arising from the environment in which they work. Risks arising from the workplace environment reduce employee productivity and affect adversely the quality of the work performed. At the same time, work-related illnesses may occur after a period of time in employees exposed to long-term risks. In order to increase productivity for the employer and employee and to protect employee health, the extent of the existing risks must be defined, the existing risks must be evaluated and precautions should be taken according to the evaluation results. At this stage, the necessity of risk assessment emerges. Risk Assessment is the study conducted to evaluate the risks arising from the workplace and the risks posed by the hazards, to rank these risks and determine the control measures for these risks [43].

Risks are caused by man, machine, material and medium. When the employee is working with excessive workload, doing work that is not suitable for his / her skills, taking responsibility more than his / her limit or carelessness, individual troubles, and mental state creates human factor risks. The chemical and physical properties of the material constitute risks arising from the material. Material fatigue, inadequate protective measures, inadequate control and maintenance, inadequate use of machinery or inadequate use of the machine pose risks to the machine. Temperature, humidity, lighting, noise, dust etc. are the sources of risk depending on the medium. While defining the risks, work equipment, materials used, employee experiences and demographic conditions, production processes and techniques are examined by considering these risk factors. According to The National Institute for Occupational Safety and Health (NIOSH), the purpose of a risk assessment is to answer three basic questions: “

- What can happen?
- How likely is it to happen?

- What are the consequences if it does happen? ”

One of the primary hazards in the workplace is the risk factors related to the musculoskeletal system. A detailed assessment should be made to reduce the risk of WMD occurrence, especially in workplaces where the use of physicalmanpower is widespread and the risks associated with musculoskeletal system are high. There are many methods developed for this purpose (Mert, 2014). These methods are OWAS (Ovako Working Posture Analyzing System), NIOSH (National Institute for Occupational Safety and Health), ManTRA (Manual Tasks Risk Assessment Tool), REBA (Rapid Entire Body Assessment), PLIBEL Plan för Identifiering av belastningsfaktorer (Plan for Identification of load factors), QEC (Quick Exposure Check), RULA (Rapid Upper Limb Assesment), MURI (Posture Analyzes).

Ergonomic risk factors are the aspects of a job or task that impose biomechanical stress on the worker. Ergonomic risk factors are the synergistic elements of MSD (musculoskeletal disorders) hazards. MSD is the discomfort that occurs in muscles, nerves, tendons, cartilage, ligaments, joints and discs (spine). Skeletal and muscular system syndromes consist of ordinary body movements, such as bending, straightening, holding, grip, bending and stretching. Furthermore, physical and biomechanical factors, organizational and psychosocial factors, individual and personal factors play a role in the development of musculoskeletal diseases [44].

Musculoskeletal system diseases have an important place among the causes of disability and they have a significant impact on the quality of life and living areas. They also have a high socioeconomic burden. According to World Health Organization musculoskeletal conditions are the second largest contributor to disability worldwide, with low back pain being the single leading cause of disability globally. Also, musculoskeletal conditions significantly limit mobility and dexterity, leading to early retirement from work, reduced accumulated wealth and reduced ability to participate in social roles. In these diseases, a better life is possible with early diagnosis and treatment.

Many methods are used in ergonomic risk assessment. Observational scales from these methods can be applied easily because they are simple and do not divide the work.

Methods based on observational scales are NIOSH, RULA, SI, OCRA, QEC, REBA, and OWAS. As for other ergonomic Risk Assessment Methods, include personal survey methods and direct measurement methods. Personal survey methods are subjective questionnaires such as Cornell Musculoskeletal Discomfort Questionnaire and used to assess the risks associated with musculoskeletal diseases. Direct measurement methods which include electromyography (EMG), goniometer, biomechanical analysis tools and optical instruments [45].

3.3.1. REBA (Rapid Entire Body Assessment) Method

REBA is a postural analysis tool developed by Hignett and McAtamney (2000) to evaluate the risk of work-related musculoskeletal disorders without the need for ergonomics or expensive equipment. REBA is used for variety of tasks and assessment of working postures found in health care and other service industries [46]. In order to implement the REBA method, it is recommended to analyze with workers' video or photo which is taken during working hours. Subsequently, based on this video and photography records, the movement which is repeated frequently, forcing the worker and requiring physical force is selected and analyzed using the related method. Flow diagram of REBA risk level calculation are shown in the Figure3.1.

In accordance with REBA method, body parts are divided into two groups, A and B;

Group A: trunk, neck, and legs

Group B: shoulders, elbows, and wrists

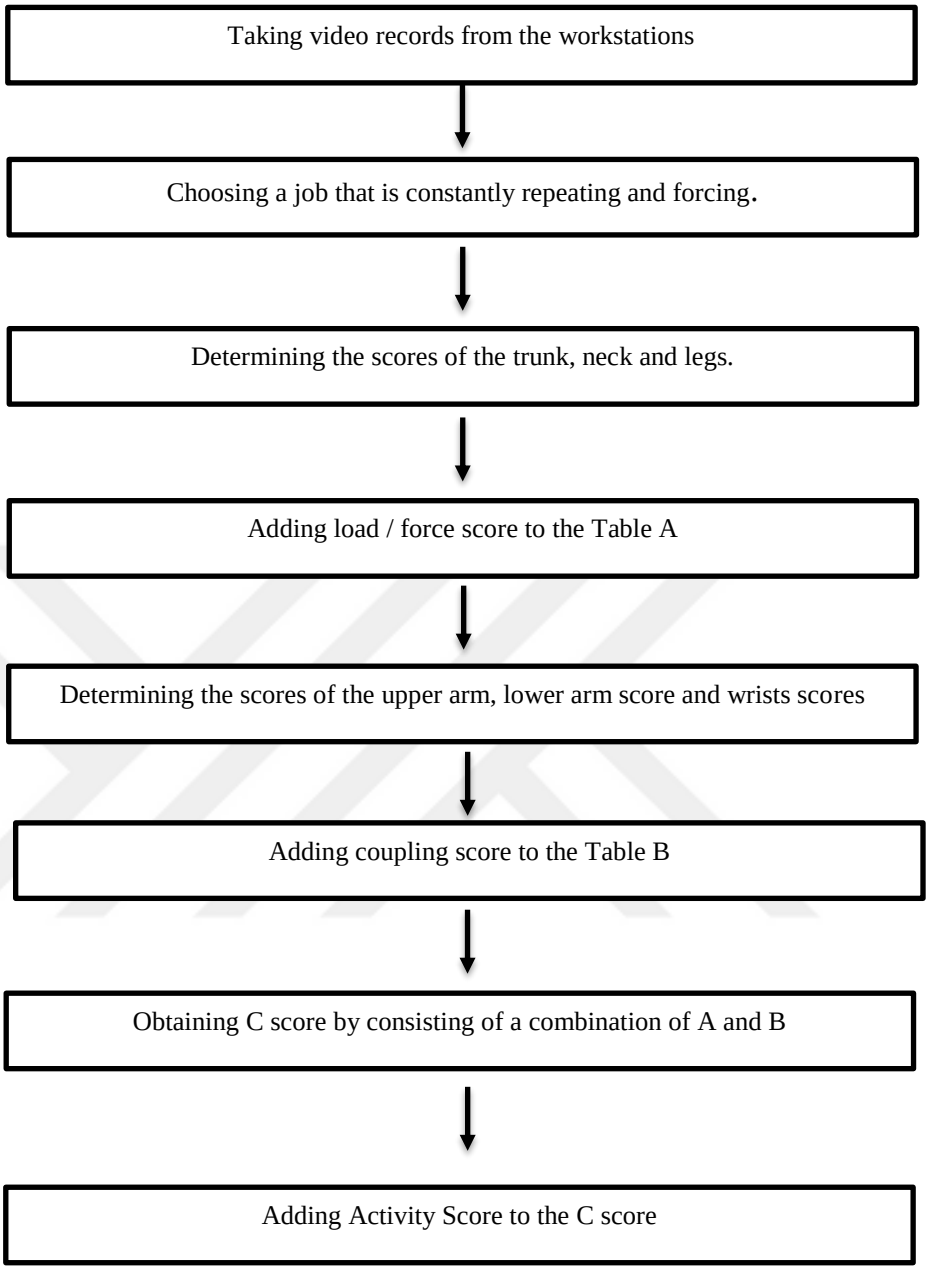


Figure 3.1 Flow diagram of research method

A score is calculated for each body part based on factors such as the range and direction of the joint motion, the amount of force applied, the condition of the load clutch, and activity [47]. Firstly, for the group A the scores of the trunk, neck and legs are determined separately. And a score consisting of a combination of these scores is determined in order to produce Table A (see in Table 3.1).

Table3.1 Table used for posture score A, Table A

Table A		Neck											
		1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	3	4	5	3	4	5	6	4	5	6	7
	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

After the values of Table A are found, by adding load / force score to the Table A, Score A value is calculated so that Table C can be created. Similarly, group B score are calculated by using Table 3.2 which includes upper arm, lower arm and wrists scores.

Table 3.2 Table used for posture score B, Table B

Table B		Lower Arm					
		1			2		
	Wrist	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

Table B score and the Coupling score for each hand involved and enter the scores in the B boxes. Then, using Table C (see in Table 3.3), C score, consisting of a combination of A and B scores is obtained. At the end, the score of Posture A and Posture B is used to find the final result of investigation that is Score C after looking

in table C for final result the score of posture A and posture B is observed and it gives the result final score C.

Table3.3 Table used for posture score C, Table C

Table C												
Score A	Score B											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	11	10	10	11	11	11	11	12	12	12	12	12
11	12	11	11	11	12	12	12	12	12	12	12	12
12	13	12	12	12	12	12	12	12	12	12	12	12

This score is than added to the Activity to get REBA score [37]. Risk level of postures and actions to be taken are determined in pursuant of Table 3.4. Additionally, the use of the REBA worksheet shown in Appendix A eases calculation of REBA risk levels.

Table 3.4 Analysis of REBA

REBA Score	Risk Level	Action
1	Negligible	No action required
2-3	Low	Low risk, change may be needed
4-7	Medium	Medium risk, further investigation, change soon
8-10	High	High risk, investigate and implement change
11-15	Very High	Very high risk, implement change

3.3.2. RULA (Rapid Upper Limb Assessment) Method

RULA is a method that is used to evaluate risk caused by upper body movements. RULA method can be used to determine the risks associated with the individual's muscle functions, neck, torso and upper extremities, without using any equipment. Measures can be taken by determining the risks of the individual working through systematic observations. RULA is used for many operations such as hand and machine packaging operations, computer and keyboard operation, sewing operations [48].

In accordance with RULA method, body parts are divided into two groups, A and B;

Group A: upper arm, lower arm, wrist, wrist twist

Group B: neck, trunk, and legs

Working posture of each movement will be processed according to the steps in the RULA method as follows [49] :

Table 3.5 Table used for posture score A in RULA method, Table A

TABLE A		Wrist Score							
Upper Arm	Lower Arm	Wrist Twist		Wrist Twist		Wrist Twist		Wrist Twist	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	7
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

1. Evaluate posture for group A (upper arm, lower arm, wrist, wrist twist) with Table 3.5.

2. Add muscle use and force scores to group A score.

3. Find Row in Posture Score C from Table 3.7

4. Evaluate posture for group B (neck, trunk, and legs) with Table 3.6 .

Table 3.6 Table used for posture score B in RULA method

Table B. Trunk Posture Score												
Neck Posture Score	1		2		3		4		5		6	
	Legs		Legs		Legs		Legs		Legs		Legs	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

5. Add muscle use and force scores to group B score.

6. Find Colum in Posture Score C from Table 3.7.

Table 3.7 Table used for posture score C in RULA method

TABLE C		Neck,Trunk,Leg Score						
		1	2	3	4	5	6	7+
Wrist / Arm Score	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8+	5	5	6	7	7	7	7

7. Determine RULA score and action to be taken.

RULA action levels report the urgency of the need to change the working posture, taking into account the risk of injury to the employee.

Action level 1 - The RULA score indicates that 1-2 employees are not at risk of injury and have a good posture.

Action level 2 - RULA score 3-4 indicates that the employee's posture is at risk of injury and that posture needs to be investigated and improved.

Action level 3 - RULA score 5-6 means that the employee is working in a weak posture with a risk of injury from the work posture, and that this should be investigated and corrected in the near future to prevent an injury.

Action level 4 - RULA score 7-8 indicates that the employee is working in the worst posture, and investigations and changes must be made immediately [50].

3.3.3. NIOSH (National Institute for Occupational Safety and Health) Method

NIOSH (National Institute for Occupational Safety and Health), US National Institute for Occupational Health and Safety; established to ensure that employees work in safe and healthy working conditions. It is an organization that works to educate and inform employees and employers on the basis of developing technology and advancing science. NIOSH works to prevent occupational accidents and injuries, provides constructive advice to increase occupational health and safety in the workplace, and aims to apply occupational health and safety worldwide to certain standards by providing international cooperation [51]. In 1981, the National Institute for Occupational Health and Safety (NIOSH) in the United States published an equation to determine weight limits for workers performing lifting tasks. The weight limits provided by the equation depend on factors such as the vertical position of the load, the distance the load is lifted, and the frequency with which the load is lifted [52]. In 1993, NIOSH published the revised NIOSH lift equation (NLE), a mathematical equation using the proposed weight limit (RWL) and lift index (LI). Later, NIOSH published an application guide that provides definitions and procedures for the proper use of equations [53]. Revised lifting equation develops new assessment methods for use in asymmetric lifting tasks. The revised lifting equation also provides guidelines for a variety of lifting tasks than the previous equation. The primary product for NIOSH's output is Recommended Weigh Limit (RWL), which defines the maximum acceptable weight limit or load that almost all healthy workers can lift or lower during the work period. The RWL calculation determines whether the lifted or lowered weight is heavy for the work performed.

RWL is represented by the following equation:

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM \quad \textbf{(3.1)}$$

where LC is the load constant and other factors in the equation are:

- HM, the Horizontal Multiplier factor,
- VM, the Vertical Multiplier factor,
- DM, the Distance Multiplier factor,
- FM, the Frequency Multiplier factor,
- AM, the Asymmetric Multiplier factor, and
- CM, the Coupling Multiplier factor.

The multipliers are determined from measurements of the horizontal (H) and vertical (V) location of the load from the midpoint between the workers feet, the vertical travel distance (D) of the lift, the angle of asymmetry (A) between the workers mid-sagittal line and the asymmetry line of the load at the lift-off point, the coupling classification (C), and the frequency rate and duration of lifting. The multipliers cannot exceed a value of 1.0.

The parameters are shown in Figure 3.2.

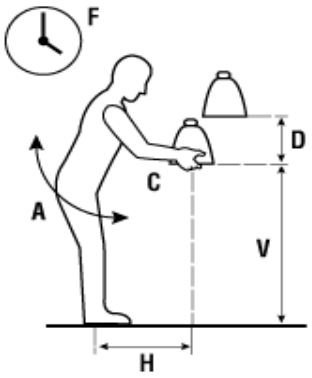


Figure 3.2 Parameters in RWL method [53]

LC,Load Constant: The specified load constant is used as 23 kg or 51 lb. The load constant is based on an acceptable weight which can be lifted under optimal conditions.

HM, the Horizontal Multiplier factor: The horizontal position of the object is determined by measuring the distance between the point projected on the ground just below the midpoint of the object or both hands and the midpoint between the inner ankle bones. HM is calculated as 25 / H for cm, 10/H for inches. If H is less than 25 (10 inches) cm, it takes 1.0. If it exceeds 63 centimeters, the multiplier is zero; because over 63 cm (25 inches) exceed the access capacity of some workers. The table with the calculated horizontal multipliers corresponding to the horizontal distances is shown in Appendix C1.

VM, the Vertical Multiplier factor: Vertical distance is the value of the height of the midpoint of both hands from the floor in centimeters or inches. VM is calculated as {1-[0,003 x (V-75)]} for cm {1-(.0075 [V-30]} for inches. If the vertical placement is over 175 centimeters (70 inches), the VM is zero. Because it exceeds the vertical access capacity of some employees.

DM, the Distance Multiplier factor: It is the distance in centimeters or inches between the point where the load starts to be lifted and the last point where the lifting process ends. DM is calculated with the formula [0.82 + (1.8/D)] for in inches, and [(.82 + (4.5/D)] for in centimeters. The vertical travel distance must be between 25 centimeters (10 inches) and 175 centimeters (70 inches). The distance variable (DM) is based on the vertical path the load takes from its origin to its destination.

FM, the Frequency Multiplier factor: The average number of lifts per minute being evaluated is the lifting frequency. Frequency multiplier table is shown in Appendix C4.

AM, the Asymmetric Multiplier factor: The asymmetric angle is the value in degrees of trunk and shoulder rotation required for the lifting task. AM is calculated as [1- 0,0032xA].

CM, the Coupling Multiplier factor: The quality of handling or grasping the lifted load is classified as good, fair or poor. Coupling multiplier factor identified as a good if the lifted object has a suitable handle for the hands or without a handle but can easily be grasped by hands and fingers. When the object does not have a handle, and held by the worker from under the subject, due to its size, shape, and stiffness then coupling multiplier factor would be defined as “fair”. If the object cannot be easily grasped because of the fact that the object is slippery, sharp-edged or soft-edged, "poor" is selected.

The tables in which include the calculated multipliers corresponding to the horizontal, vertical, distance, asymmetric angle, frequency and coupling are shown in Appendix C1-C5, respectively.

In addition, Lifting Index (LI) is used to calculate the relative stress associated with the lifting task. This index is the ratio of the weight lifted to the Recommended Weight Limit as:

$$LI = \frac{Load\ Weight\ (L)}{Recommended\ Weight\ Limit\ (RWL)} \quad \textbf{(3.2)}$$

If the result after application of the above ratio is greater than 1, the lifting operation is a danger for the worker's health. Therefore, in the process with this risk, necessary improvements must be made in order to reduce to lifting index to less than 1 [52].

3.4. Work-Related Musculoskeletal Diseases

WSMD, which has an important place in occupational health and safety, develops due to physical and physiological exposure of employees to working conditions. Work-related musculoskeletal diseases are one of the leading causes of work-related injuries in employees, leading to high diagnosis and treatment expenses, loss of working days and insurance compensation payments. It is a significant concern for managers due to costs and labor loss. Developing countries have collaborated with health companies, insurance companies, ergonomic development companies, and occupational health and safety organizations in order to avoid the increase in the prevalence of WSMD. As a result of joint efforts, regulations have been introduced in many countries

regarding mandatory health checks or compulsory health policies of companies depending on the burden of work for industry workers [4].

WMSDs have received many names because they are very difficult to identify in disease classifications. These names are:

- Repetitive motion injuries.
- Repetitive stress injuries.
- Cumulative trauma disorders.
- Occupational cervicobrachial disorders.
- Overuse syndrome.
- Diseases of regional musculoskeletal system.
- Soft tissue diseases [55]

Examples of common WMSDs are:

- Carpal tunnel syndrome (CTS): It is a compression of the median nerve in the wrist, which can cause numbness, tingling, weakness or muscle atrophy in the hands and fingers of the wrist.
- Back injury and back pain: Incorrect posture or incorrect weight lifting can cause back pain or back injury in employees in a short time or in the long run.
- Myofascial pain in the neck and upper back: Myofascial pain syndrome is a muscle pain that can cause chronic pain in the neck and back due to injury or damage to the soft flexible connective tissue fascia.
- Shoulder bursitis: it is a painful inflammatory disease of bursa which is a cushion located at the friction points between the bone and the surrounding soft tissue. It develops as a result of difficulties and tendinitis except for systemic diseases that can affect the bursa.
- Rotator cuff tendonitis: Rotator cuff tendonitis is an inflammation of connective tissues that have a significant effect on the movement of the shoulder.

- Tennis elbow: The common starting point of the muscles that pull the wrist backwards is the area called "lateral epicondyle" on the outer side of the elbow. Tennis elbow is formed as a result of small tears and degeneration in the muscle-bone junction in this region due to repetitive difficulties.
- Thumb tendonitis or DeQuervain’s tendonitis: It is a condition that develops due to inflammation and strain of the wrist tendons (beams) of the thumb [57].

3.5. Mental Workload

Productivity is defined as the ratio of production (outputs) to the sum of the factors (inputs) which are necessary to make this production. In order to increase efficiency, enterprises try to achieve the maximum possible output with minimum input. Labor is one of the most important inputs affecting the maximum level of output targeted to increase productivity. Since increasing the level of labor force causes excessive input for the enterprise and decreases productivity, it is aimed to use the amount of labor available in the most efficient way instead of changing the level. In line with these conditions, people-centered problems should be focused and analyzes and observations should be made on employees. In line with these conditions, human-centered problems should be focused and the performance of the employees should be increased [28].

The sum of the factors that create resistance to the worker while doing the work is called the workload. This is because the clutch and gears need to be adjusted correctly when using the manual car. However, perception of workload may vary from person to person. As the employee's personal performance parameters (abilities, skills, training and experience and health status) vary from person to person; the struggle and perception of the mental workload varies from person to person. According to some scientist, as the target gets harder and the workload increases, the performance of the workers decrease, their capacity decreases, the inability to complete the task on time and the number of errors increase. In order to protect employees from these harmful effects, it is important to measure the mental workload. There is no specific method for measuring mental workload, but there are many different approaches to measure it. The most commonly used mental workload measurement techniques are NASA Task Load Index-NASA TLX, Subjective Workload Assessment Technique-(SWAT), NASA Bipolar Rating Scale, Cooper-Harper Rating Scale, Bedford Scale, Zwer Ebenen Intensitats - Scale [35]. Workload measurement techniques are generally grouped as subjective assessment scales, performance measures and psychophysiological measures [58]. Subjective assessment scales take into account questionnaires and personal opinions. The most frequently used of these methods is

the subjective assessment scales which is the least costly and requires the least effort [8]. In this method, the jobs are reported under the leadership of experts by the employee after the work is completed. Therefore, this method is effective in gathering information about the working environment and worker skills, which operators feel directly related to their mental workload.

3.5.1. NASA-Task Load Index

In the NASA-TLX method, employees make a pairwise comparison of 6 factors to assess mental workload to determine which factor is more challenging. These 6 factors are mental demand, physical demand, temporal demand, performance, effort, and frustration. Table 3.8 shows the definitions of NASA-TLX dimensions.

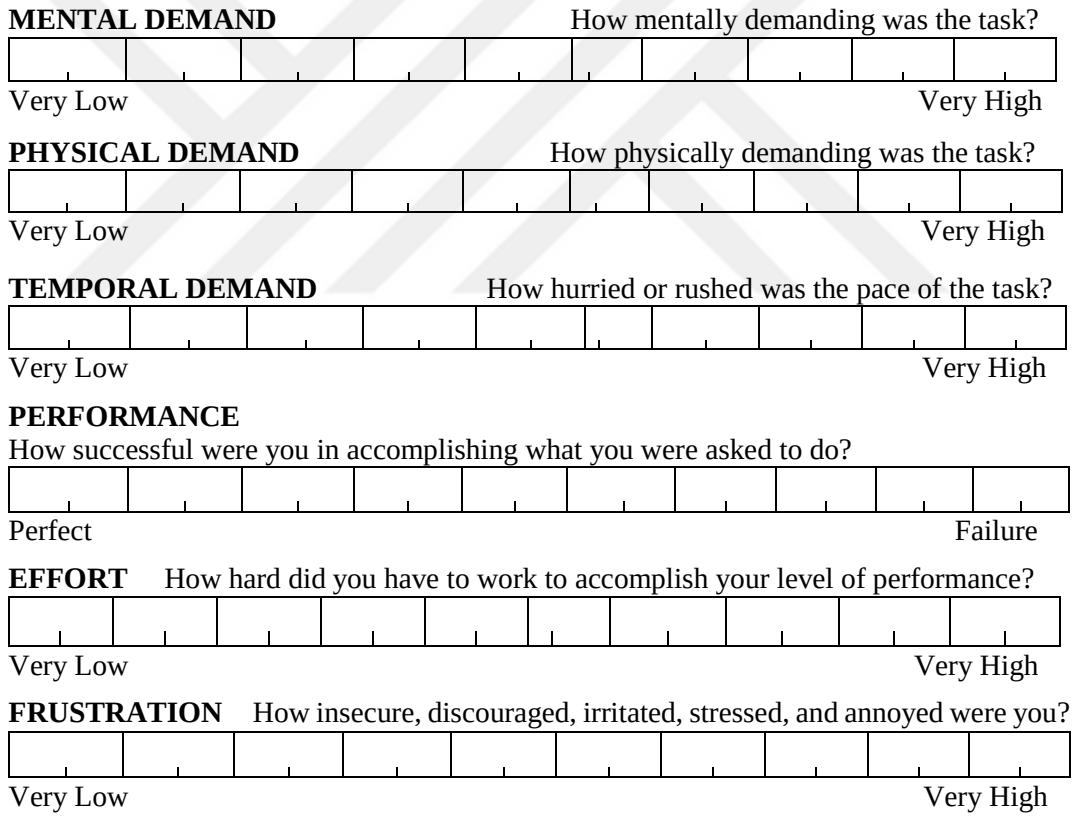


Figure 3.3 NASA Task Load Index (TLX) method assesses

In the first stage of the method, the effect of six factors on the scoring stage are determined by marking on the scale given in Figure 3.3 formed between "very low"

and "very high". Twenty-step bipolar scales are used to obtain ratings on these scales. Each scale receives a score between 0 and 100.

Table 3.8 Definitions of NASA-TLX dimensions

Factors/Dimensions	Definitions
Mental Demand	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical Demand (PD)	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand (TD)	How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance (PL)	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort (EL)	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration (FL)	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

In the second stage of the NASA-TLX comparison stage, the weight calculation is applied following 15 paired comparison sets of 6 dimensions (See in Table 3.9). The operator chooses which dimension is more relevant to the workload on all pairs of the

six dimensions. The dimension with the highest weight is the most important contribution to the mental workload.

Table 3.9 Binary Comparison of Dimensions

Dimensions	**Dimensions**
Effort	Performance
Temporal Demand	Effort
Performance	Frusturation
Physical Demand	Performance
Temporal Demand	Frusturation
Physical Demand	Frusturation
Physical Demand	Temporal Demand
Temporal Demand	Mental Demand
Frusturation	Effort
Performance	Temporal Demand
Mental Demand	Physical Demand
Frusturation	Mental Demand
Performance	Mental Demand
Mental Demand	Effort
Effort	Physical Demand

Fifteen comparisons are made in binary comparisons. In order to find the weight of each dimension, the number of times each dimension is predominantly determined is divided by the total number of binary comparisons which is 15. The score for each dimension obtained from the first part is multiplied by the weight obtained from the second part. Thus, weighted score is obtained for each dimension. Finally, the weighted score of each dimension is summed as in Equation (3.3) and the perceived workload score is found.

$$Mental\ Workload = MD\ \times W_{MD} + PD \times W_{MD} + PD \times W_{PD} + TD \times W_{TD}\ + FL \times W_{FL} + EL \times W_{EL} + PL \times W_{PL} \quad \textbf{(3.3)}$$

Where;

MD: Mental Demand score between 0-100,

PD: Physical Demand score between 0-100,

TD: Temporal Demand score between 0-100,

FL: Frustration score between 0-100,

EL: Effort score between 0-100,

PL: Performance score between 0-100,

W_{MD}: The weight of the mental demand,

W_{PD}: The weight of the physical demand,

W_{TD}: The weight of the temporal demand,

W_{FL}: The weight of the frustration,

W_{EL}: The weight of the effort,

W_{PL}: The weight of the performance [58].

CHAPTER 4

EXPERIMENTAL STUDY

This study was implemented on the integrated meat-dairy food facility in Konya which is the largest meat-milk integrated facility in the world. The facility was established on a total open area of 343,143 thousand square meters and a closed area of 85,978 thousand square meters. The facility, which currently has a capacity of processing 1200 tons of raw milk, and processing a total of 1650 feeds, per day and can increase to 2,000 tons of raw milk per day and 450 cattle 1200 small sheep per day when it reaches to its full capacity production.

In the study, employees of the integrated facility in Konya were used as subjects to measure the effects of ergonomic risk levels on their mental load. After data collection, regression analysis was used to determine whether there was a relationship between ergonomic risk levels and the mental workloads. REBA, RULA and NIOSH risk assessment methods were used to measure ergonomic risk levels. Ergofellow 3.0 software was used to determine the risk levels with these methods.

In addition, the NASA TLX score for mental load measurement was acquired by using questionnaires given to the score employees. The work done by 84 workers in the factory was found suitable for this study. After informing these 84 employees about the study and obtained permission from them, studies were started.

4.1. Ergofellow 3.0 Software

ErgoFellow 3.0 software has 17 ergonomic tools (NIOSH (Revised Lifting Equation), OWAS (Ovako Working Posture Analysing System), RULA (Rapid Upper Limb Assessment) ,REBA (Rapid Entire Body Assessment), Suzanne Rodgers, Moore and Garg (Strain Index), Discomfort Questionnaire, QEC (Quick Exposure Check), Lehmann, Image Analysis, Video Analysis, Anthropometry, Calculation of Force, PPE (Personal Protective Equipment), Heat Stress, Noise Exposure (OSHA), Typing Evaluation) that allow you to analyze workplace conditions to reduce occupational risks and increase productivity. In this study REBA, RULA and NIOSH tools were

used. 17 ergonomic tools of the ErgoFellow 3.0 software images related to this study is shown in Appendix E.

4.2. Application of REBA Method

The 84 workers selected from the workers working in the production part of the factory were analyzed individually while they carried out their work with respect to the work postures. Video recordings were made of the stance of the workers depicting their movements during their work. After the video was taken, snapshots of 45 postures were taken for each worker from the videos for employee posture analysis. Snapshots were analyzed to fill the scores in the Ergofellow 3.0 software REBA module. Thus, overall body posture assessment using the REBA method was performed for all of 84 workers. Finally, the REBA scores obtained from the analysis of 45 postures in each operation were averaged and the REBA score of each operation was found.

REBA analysis results for 45 postures in operation 1 is shown in Table 4.1. In this operation, packaged 200 ml milk is taken from the production line and placed on pallets to be transported to the storage area by forklift trucks. One pack of milk is 200 ml and each cardboard box contains 27 packs of milk.

The REBA values of the other operations, calculated as a result of the REBA scores of the 45 postures, are shown in Table 4.1.

Table 4.1 REBA Scores for Operation 1.

Operation 1				
Number of Task	**REBA Score**	**Risk Level**	**Action**	**Picture of the task**
1	8	High	High risk, investigate and implement change	
2	5	Medium	Medium risk, further investigation, change soon	
3	10	High	High risk, investigate and implement change	
4	5	Medium	Medium risk, further investigation, change soon	
5	6	Medium	Medium risk, further investigation, change soon	

Table 4.1 REBA Scores for Operation 1 (Continued).

Operation 1				
Number of Task	**REBA Score**	**Risk Level**	**Action**	**Picture of the task**
6	9	High	High risk, investigate and implement change	
7	5	Medium	Medium risk, further investigation, change soon	
8	8	High	High risk, investigate and implement change	
9	8	High	High risk, investigate and implement change	
10	7	Medium	Medium risk, further investigation, change soon	

Table 4.1 REBA Scores for Operation 1(Continued).

Operation 1				
Number of Task	**REBA Score**	**Risk Level**	**Action**	**Picture of the task**
11	10	High	High risk, investigate and implement change	
⋮	⋮	⋮	⋮	⋮
37	8	High	High risk, investigate and implement change	
38	9	High	High risk, investigate and implement change	
39	5	Medium	Medium risk, further investigation, change soon	
40	7	Medium	Medium risk, further investigation, change soon	

Table 4.1 REBA Scores for Operation 1(Continued).

Operation 1				
41	9	High	High risk, investigate and implement change	
42	5	Medium	Medium risk, further investigation, change soon	
43	7	Medium	Medium risk, further investigation, change soon	
44	5	Medium	Medium risk, further investigation, change soon	
45	5	Medium	Medium risk, further investigation, change soon	
AVR	6.444444444	Medium	Medium risk, further investigation, change soon	

4.3. Application of RULA Method

As in the above-described REBA method, the RULA method was used to examine the 45 postures obtained from the videos for each operation.

In the application of REBA method, features such as work activities carried out in processes and load amounts carried were mentioned. The following table shows the results of the 45 postures in operation 1 analyzed by the RULA method by using Ergofellow 3.0 software and actions that have to be taken.

All RULA risk levels in Operation 1 were found to be 7. For a more efficient and healthy work environment, investigation of postures and implementation of changes is imperative.

The RULA values of the other operations, calculated as a result of the REBA scores of the 45 postures, are shown in Table 4.10.

4.4. Application of NIOSH Lifting Equation

The measurements required for 84 the processes selected from the integrated meat & diary plant are written on the worksheet of the NIOSH weight lifting equation are given in Appendix C. In order to perform NIOSH, each operation was separated according to different parameters in itself and as a result an average NIOSH score was obtained for each operation. Three different measurement values were determined for operation one and a NIOSH value was determined for the operation by averaging the values obtained from these measurements. The first load lowering tasks in operation 1 is shown in Figure 4.1 and Figure 4.2.



Figure 4.1 Task 1-Origin



Figure 4.2 Task 1-Destination

Step 1: Measurement and Monitoring of Work Variables

Table 4.2 NIOSH Lifting Variables for task 1

	NIOSH Lifting Variables								
Lifting Task	**H** Horizontal Location	**V** Vertical Location	**D** Travel Distance	**A** Angle of Asymmetry	**C** Coupling	**F** Frequency	**L** Ave.Load Lifted	**L** Max Load Lifted	**Dur** Duration
Lowering milk cartons-Origin	34	81	42	32	Fair	11	4.86 kg	4.86 kg	8 hours
Lowering milk cartons-Destination	20	34	42	32	Fair	11	4.86 kg	4.86 kg	8 hours

Step 2: Finding Multipliers and RWL

Table 4.3 NIOSH lifting equation multipliers for task 1

	NIOSH Lifting Multipliers								
Lifting Task	**HM**	**VM**	**DM**	**AM**	**C**	**F**	**L**	**L**	**Dur**
Lowering milk cartons-Origin	0.77	0.99	0.91	0.87	1.00	0.00	4.86 kg	4.86 kg	Long
Lowering milk cartons-Destination	1.00	0.87	0.92	0.90	0.95	0.00	4.86 kg	4.86 kg	Long

Using Equation 3.1 from the determination of NIOSH method above, RWL is calculated as follows;

$$Origin\ of\ RWL = 23 \times 0.77 \times 0.99 \times 0.91 \times 0.87 \times 1 \times 0 \times 4.86 = 0$$

$$Destination\ of\ RWL = 23 \times 1 \times 0.87 \times 0.92 \times 0.90 \times 0.95 \times 0 \times 4.86 = 0$$

The result of the evaluation of the working positions is the initial lifting index 0 and the arrival lift index 0.

$$Lifting\ Index\ (LI) = N/A^{*}$$

N/A^* = Since one of the multipliers is 0, the weight lifting index will be greater than 3. This lifting may exceed the capabilities of safely performing the lift for nearly all workers. Redesign of the lifting task is recommended.

The second load lowering task in operation 1 is shown Figure 4.3 and Figure 4.4 below.



Figure 4.3 Task 2 - Origin



Figure 4.4 Task 2- Destination

Step 1: Measurement and Monitoring of Work Variables

Table 4.4 NIOSH Lifting Variables for task 2

	NIOSH Lifting Variables								
Lifting Task	**H** Horizontal Location	**V** Vertical Location	**D** Travel Distance	**A** Angle of Asymmetry	**C** Coupling	**F** Frequency	**L** Ave.Load Lifted	**L** Max Load Lifted	**Dur** Duration
Lowering milk cartons-Origin	26	81	34	43	Fair	11	4.86 kg	4.86 kg	8 hours
Lowering milk cartons-Destination	67	47	34	40	Fair	11	4.86 kg	4.86 kg	8 hours

Step 2: Finding Multipliers and RWL

Table 4.5 NIOSH lifting equation multipliers for task 2

	NIOSH Lifting Multipliers								
Lifting Task	**HM**	**VM**	**DM**	**AM**	**C**	**F**	**L**	**L**	**Dur**
Lowering milk cartons-Origin	0.98	0.99	0.95	0.86	1.00	0.00	4.86 kg	4.86 kg	Long
Lowering milk cartons-Destination	0.00	0.91	0.95	0.87	0.95	0.00	4.86 kg	4.86 kg	Long

Using Equation (1) from the determination of NIOSH method above, RWL is calculated as follows;

$$Origin\ of\ RWL = 23 \times 0.98 \times 0.99 \times 0.95 \times 0.86 \times 1 \times 0 \times 4.86 = 0$$

$$Destination\ of\ RWL = 23 \times 0 \times 0.91 \times 0.95 \times 0.87 \times 0.95 \times 0 \times 4.86 = 0$$

The result of the evaluation of the working positions is the initial lifting index 0 and the arrival lifting index 0.

$$Lifting\ Index\ (LI) = N/A^*$$

N/A^* = Since one of the multipliers is 0, the weight lifting index will be greater than 3. This lift may exceed the capabilities of safely performing the lift for nearly all workers. Redesign of the lifting task is recommended.

The third load lifting task in operation 1 is shown Figure 4.5 and Figure 4.6 below.



Figure 4.5 Task 3-Origin



Figure 4.6 Task 3-Destination

Step 1: Measurement and Monitoring of Work Variables

Table 4.6 NIOSH Lifting Variables for task 3

	NIOSH Lifting Variables								
Lifting Task	**H** Horizontal Location	**V** Vertical Location	**D** Travel Distance	**A** Angle of Asymmetry	**C** Coupling	**F** Frequency	**L** Ave.Load Lifted	**L** Max Load Lifted	**Dur** Duration
Lowering milk cartons-Origin	25	81	19	42	Fair	11	4.86 kg	4.86 kg	8 hours
Lowering milk cartons-Destination	26	62	19	40	Fair	11	4.86 kg	4.86 kg	8 hours

Step 2: Finding Multipliers and RWL

Table 4.7 NIOSH lifting equation multipliers for task-3

	NIOSH Lifting Multipliers								
Lifting Task	**HM**	**VM**	**DM**	**AM**	**C**	**F**	**L**	**L**	**Dur**
Lowering milk cartons-Origin	0.98	0.99	1	0.86	1.00	0.00	4.86 kg	4.86 kg	Long
Lowering milk cartons-Destination	0.67	0.96	1.00	0.87	0.95	0.00	4.86 kg	4.86 kg	Long

Using Equation (1) from the determination of NIOSH method above, RWL is calculated as follows;

$$Origin\ of\ RWL = 23 \times 0.98 \times 0.99 \times 1 \times 0.86 \times 1 \times 0 \times 4.86 = 0$$

$$Destination\ of\ RWL = 23 \times 0.67 \times 0.96 \times 1 \times 0.87 \times 0.95 \times 0 \times 4.86 = 0$$

The result of the evaluation of the working positions is the initial lift index 0 and the arrival lift index 0.

$$Lifting\ Index\ (LI) = N/A^{*}$$

N/A^{*} = Since one of the multipliers is 0, the weight lifting index will be greater than 3. This lift may exceed the capabilities of safely performing the lift for nearly all workers. Redesign of the lifting task is recommended.

4.5. Application of NASA TLX

In this study, a questionnaire (see in Appendix D) consisting of two parts was used as a data collection tool. Before completing the questionnaire, brief information about NASA TLX was given to workers by the researchers of the study. The operators were asked whether they had any questions about the survey. In the first part, the NASA TLX scale which examined the mental workload in six dimensions as mental demand, physical demand, temporal demand, performance, effort, and frustration were evaluated by the employees. In the second stage of the survey, the paired comparisons of these 6 scores were made by the workers. The survey shows the employee's choice from the paired selection weighting task and the raw scores from the 6 rating scales. Scale ratings are scored based on where the employee marks the scale. The marks they mark vary from 0 to 100 in 5-point increments, with points for the mark above or immediately above the mark. Weighted averages are calculated by multiplying the raw score of each scale by the number of times the associated workload factor is selected in the paired selection task and then dividing it by the sum of the weights. As a result of the paired comparison of dimensions, the weight values of the paired comparisons found by the survey applied to 84 employees are shown in Table 4.8. The scores for each dimension obtained from the first part were multiplied by the weights acquried from the second part. The weights acquried from the second part is shown in Table 4.9. Thus, a weighted score was obtained for each dimension. Finally, the weighted score of each dimension was summed and the perceived workload scores shown in Table 4.10. were found.

Table 4.8 The result of the pairwise comparison of dimension

Operation		1	2	3	4	5	6	7	8	...	78	79	80	81	82	83	84
Resulting Weights	Mental	0.33	0.13	0	0.07	0.07	0.27	0.07	0.13	...	0.33	0.2	0.27	0.13	0.13	0.33	0.07
	Physical	0.07	0	0.07	0.07	0.13	0.13	0.2	0.27	...	0.07	0.33	0.13	0.2	0.2	0.07	0.2
	Temporal	0.27	0.2	0.2	0.2	0.13	0.27	0.2	0.2	...	0.27	0	0.13	0.2	0.2	0.27	0.2
	Performance	0.2	0.27	0.27	0.33	0.2	0.2	0.13	0.07	...	0.2	0.07	0.27	0.2	0.2	0.2	0.07
	Effort	0.13	0.33	0.33	0.2	0.27	0.07	0.2	0.07	...	0.13	0.2	0.07	0.2	0.13	0.13	0.27
	Frustration	0	0.13	0.13	0.13	0.2	0.07	0.2	0.27	...	0	0.2	0.13	0.07	0.13	0	0.2
Total	Mental	5	2	0	1	1	4	1	2	...	5	3	4	2	2	5	1
	Physical	1	0	1	1	2	2	3	4	...	1	5	2	3	3	1	3
	Temporal	4	3	3	3	2	4	3	3	...	4	0	2	3	3	4	3
	Performance	3	4	4	5	3	3	2	1	...	3	1	4	3	3	3	1
	Effort	2	5	5	3	4	1	3	1	...	2	3	1	3	2	2	4
	Frustration	0	2	2	2	3	1	3	4	...	0	3	2	1	2	0	3
1	Mental Demand	1	1		1		1	1		...	1					1	
	Physical Demand			1		1			1	...		1	1	1	1		1
2	Temporal Demand	1	1	1			1	1	1	...	1			1		1	1
	Performance				1	1				...		1	1		1		
3	Effort	1	1	1		1				...	1			1		1	1
	Frustration				1		1	1	1	...		1	1		1		
4	Mental Demand	1				1	1		1	...	1	1	1			1	1
	Temporal Demand		1	1	1			1		...				1	1		
5	Effort	1	1	1	1	1	1			...	1				1	1	1
	Physical Demand							1	1	...		1	1	1			
6	Performance	1	1	1	1		1			...	1		1	1		1	
	Frustration					1		1	1	...		1			1		1
7	Mental Demand	1					1			...	1		1	1	1	1	
	Effort		1	1	1	1		1	1	...		1					1
8	Frustration								1	...		1					
	Temporal Demand	1	1	1	1	1	1	1		...	1		1	1	1	1	1
9	Performance	1	1	1	1	1	1	1		...	1		1	1	1	1	
	Physical Demand								1	...		1					1
10	Mental Demand	1							1	...	1	1	1			1	
	Performance		1	1	1	1	1	1		...				1	1		1
11	Effort		1	1		1		1		...		1		1			1
	Temporal Demand	1			1		1		1	...	1		1		1	1	
12	Physical Demand	1			1		1	1	1	...	1	1			1	1	
	Frustration		1	1		1				...			1	1			1
13	Mental Demand	1	1				1			...	1	1	1	1	1	1	
	Frustration		1	1	1	1		1	1	...							1
14	Performance	1	1	1	1				1	...	1		1			1	
	Physical Demand					1	1	1		...		1		1	1		1
15	Effort		1	1	1			1		...		1	1	1	1		
	Temporal Demand	1				1	1		1	...	1					1	1

... = 76 intermediate operations

Table 4.9. The weights acquried from the second part of NASA TLX

	Resulting Weights					
Operation	Mental	Physical	Temporal	Performance	Effort	Frustration
1	10	10	10	10	10	10
2	10	10	15	10	95	10
3	10	10	15	10	10	10
4	40	10	50	90	80	45
5	5	50	55	20	55	10
6	45	90	20	40	95	25
7	5	45	45	10	95	10
8	95	95	100	90	95	95
⋮	⋮	⋮	⋮	⋮	⋮	⋮
78	60	10	45	15	25	10
79	10	75	10	60	55	10
80	35	10	10	70	10	20
81	50	50	35	95	10	75
82	50	65	20	95	45	35
83	50	10	30	25	35	10
84	65	10	50	60	90	50

4.6. Regression Analyses

Regression analysis is used to measure the relationships between two or more variables. Regression develops an estimating equation using the relationship between the dependent and independent variable (s) and the linear curve concept. Once the relationship between the variables is determined, the score of the dependent variable can be estimated when the score of the independent variable (s) is known.

In this study, the relationship between work postures and mental workload was evaluated by multivare regression analysis by using data from Table 4.10.

The dependent variable is the predicted variable in the regression model. This variable is assumed to be associated with the argument. The independent variable is an explanatory variable in the regression model; is used to estimate the value of the dependent variable. In the study, the dependent variable was mental workload, NASA TLX scores. While the mental workload is a dependent variable, the ergonomic risk levels of working postures carrying and lifting are independent variables. Before starting the regression analysis, whether there was any significance between the variables was tested with correlation analysis. As a result of the correlation analysis, as seen in figure 4.7, there is a relationship between the variables.

Using the data in Table 4.10, the regression model established with the hypothesis that the risks arising from working postures affect mental workload was statistically significant with the values which are F=27.852 and P<0.05 (see in Figure 4.8).

The effect of independent variables on the dependent variable is obtained by the formula in equation 4.1.

$$Y_{NASATLX} = \alpha + \beta X_{REBA} - \beta X_{RULA} + \beta X_{NIOSH} + \varepsilon$$

(4.1)

H_1: The increase in REBA Risk level increases mental workload.

H_2: RULA The increase in risk level increases mental workload.

H_3: Increase in NIOSH Lifting Eqution value increases mental workload.

Correlations

		RebaResult	RulaResult	NioshResult	Nasa TLXResult
RebaResult	Pearson Correlation	1	,885**	,664**	,570**
	Sig. (2-tailed)		,000	,000	,000
	N	84	84	84	84
RulaResult	Pearson Correlation	,885**	1	,615**	,444**
	Sig. (2-tailed)	,000		,000	,000
	N	84	84	84	84
NioshResult	Pearson Correlation	,664**	,615**	1	,678**
	Sig. (2-tailed)	,000	,000		,000
	N	84	84	84	84
NasaTLXResult	Pearson Correlation	,570**	,444**	,678**	1
	Sig. (2-tailed)	,000	,000	,000	
	N	84	84	84	84

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4.8 Correlation analyses result

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	27927,748	3	9309,249	27,852	,000[a]
	Residual	26739,090	80	334,239		
	Total	54666,838	83			

a. Predictors: (Constant), NioshResult, RulaResult, RebaResult

b. Dependent Variable: NasaTLXResult

Figure 4.9 Significance test result

On the other hand, when individual significance tests of independent variables are examined, it was determined that REBA risk level positively affects the increase in mental workload (β=.508; t=2.858; p<0.05), RULA risk level negatively affects mental workload increase (β=-.346; t=-2.05; p<0.05), NIOSH Lifting Equation positively affects mental workload inrease (β=.553; t=5.2; p<0.05). Looking at the explanatory power of these three variables in the model, the explanatory power of the model is 51%.

Table 4.10 REBA, RULA, NLE and NASA TLX results

OPERATION	REBA Results	RULA Results	NIOSH Result	NASA TLX Results
Operation 1	6.44	7.00	3.10	10.00
Operation 2	7.71	7.00	2.07	40.00
Operation 3	3.02	4.47	2.03	11.00
Operation 4	7.64	7.00	3.03	65.33
Operation 5	7.64	7.00	3.10	35.00
Operation 6	6.58	6.40	1.82	45.33
Operation7	3.80	5.00	1.07	40.67
Operation8	6.80	6.31	1.97	95.67
Operation9	7.09	7.00	3.10	61.33
Operation10	4.13	3.44	1.05	57.67
Operation11	7.81	7.00	2.08	46.67
Operation12	8.00	7.00	3.10	66.67
Operation13	6.24	6.12	1.77	79.33
Operation14	7.65	7.00	2.00	60.00
Operation15	6.36	7.00	3.10	48.00
Operation16	5.98	6.34	1.32	85.33
Operation17	7.98	7.00	3.10	69.67
Operation18	4.26	3.44	1.02	49.67
Operation19	3.78	4.67	3.02	52.67
Operation20	7.32	7.00	2.63	50.00
Operation21	3.06	4.00	1.97	10.00
Operation22	7.80	7.00	3.02	32.00
Operation23	5.98	6.32	1.71	42.00
Operation24	6.34	5.93	2.00	97.00
Operation25	4.43	3.82	1.01	55.00
Operation26	6.50	7.00	9.82	10.00
Operation27	3.72	3.24	2.07	10.00
Operation28	3.02	4.87	1.01	34.67
Operation29	5.74	6.43	1.54	98.67
Operation30	6.53	6.93	3.10	62.00
Operation31	1.49	2.00	0.83	12.00
Operation32	3.41	3.10	1.34	34.00
Operation33	3.22	3.41	1.42	9.67
Operation34	3.13	3.62	1.76	40.67
Operation35	8.12	7.00	3.10	88.33
Operation36	7.89	7.00	2.25	81.33
Operation37	8.84	7.00	2.54	98.00
Operation38	2.06	1.78	0.63	24.67
Operation39	3.25	4.12	1.53	10.67
Operation40	3.35	4.21	1.01	24.40

Table 4.10 REBA,RULA, NLE and NASA TLX results (Continued)

OPERATION	REBA Results	RULA Results	NIOSH Result	NASA TLX Results
Operation41	3.01	4.43	2.01	10.67
Operation42	3.32	4.08	1.76	33.33
Operation43	6.32	3.80	0.87	25.00
Operation44	3.12	5.00	0.87	23.33
Operation45	7.09	7.00	3.10	66.67
Operation46	2.10	1.88	0.93	20.67
Operation47	3.25	4.33	1.29	18.33
Operation48	7.00	7.00	3.01	67.00
Operation49	7.34	7.00	3.02	35.33
Operation50	3.05	3.50	1.58	10.00
Operation51	3.01	4.67	2.12	54.67
Operation52	3.80	5.00	1.07	39.33
Operation53	4.18	5.23	1.97	36.33
Operation54	6.21	7.00	2.65	10.00
Operation55	8.32	7.00	3.10	63.33
Operation56	6.54	7.00	2.76	10.00
Operation57	7.43	7.00	3.10	33.00
Operation58	3.52	2.87	0.25	10.33
Operation59	7.32	7.00	3.10	64.00
Operation60	5.98	6.32	1.71	47.33
Operation61	6.93	7.00	3.10	68.00
Operation62	2.22	2.62	0.55	27.33
Operation63	1.70	2.47	0.68	10.00
Operation64	7.85	5.67	1.83	47.00
Operation65	7.10	6.00	1.75	43.00
Operation66	4.13	3.44	1.05	52.00
Operation67	7.24	7.00	2.15	43.00
Operation68	8.00	7.00	3.10	72.67
Operation69	6.34	7.00	2.91	10.00
Operation70	8.43	7.00	3.10	78.33
Operation71	4.13	3.44	1.05	52.00
Operation72	7.03	7.00	3.10	96.00
Operation73	3.13	2.46	1.00	48.00
Operation74	4.93	3.69	1.85	56.00
Operation75	6.10	7.00	3.10	8.33
Operation76	3.21	4.67	5.21	10.33
Operation77	9.13	7.00	3.10	96.33
Operation78	6.00	7.00	3.10	39.00
Operation79	7.93	7.00	2.35	44.00
Operation80	3.20	4.96	1.04	34.00
Operation81	7.20	7.00	1.96	49.67
Operation82	7.10	6.40	1.99	53.33
Operation83	3.52	5.43	1.07	35.00
Operation84	3.55	4.67	2.98	54.33

CHAPTER 5

RESULTS AND DISCUSSION

The main goal of this study was to investigate the effects of worker postures and incorrect load-lifting levels on mental workload. The research mainly focused on the evaluation of the relationship between the values obtained as a result of measuring postures and lifting equations the values obtained as a result of mental workload. The three techniques were used for posture analyses and a method of mental workload is used to obtain workload scores. In general, most researchers assumed that work posture risk level doesn't affect the mental workload of workers and they studied them separately. However, it should be taken into consideration that the working posture that the employee exhibits and the lifting or lowering load during the work may cause mental fatigue of the employee It is important for employers and employees to know that improving worker postures is effective in reducing mental workload and protect the health of the operator as well as improve their performance and increase working efficiency.

The study was conducted in an integrated meat-dairy food facility in Konya, which produces meat and dairy products. As a result of interviews with supervisors and related engineers in the factory, 84 employees were selected for the study. REBA, RULA and NIOSH Lifting Equations methods were found appropriate to evaluate the risk levels of work postures and NASA TLX methods was used to indicate the mental workload in order to study the relationship between the work postures and mental workload assessments. The video recording of the working postures of the tasks of 84 workers in performing their tasks showing their movements during the work was recorded and the video records were clipped and 45 postures were obtained from each operation. Neck position, trunk position, legs , force/load, upper-lower arm and wrist position, coupling and activity scores which are taken from the video clips were entered into the Ergofellow program, and then the REBA risk level was calculated for each task. The REBA risk level for each operation was calculated by using the arithmetic average of the REBA risk levels for the 45 tasks in each operation. Like in REBA analysis, for each tasks of 45 posture for 84 workers, upper-lower arm and wrist

twist, muscle use, force/load, neck position, trunk position and legs scores were entered as data and then the RULA risk level was calculated for each task. The RULA risk level for operations is determined by averaging 45 RULA values for 45 tasks. In the NIOSH Lifting Equation method, measurements taken from employees during the application were used as data and also video recordings taken for each operation. Since there are different measurement values in each operation for the NIOSH Lifting Equation application, the operations were grouped according to measurement differences. The risk levels according to NIOSH Lifting Equation are identified by taking the average of the obtained NIOSH lifting indices. As for the mental load measurement, mental load levels were described with NASA TLX method for the employees in each operation based on the questionnaire results. REBA risk levels, RULA risk levels, NIOSH Lifting index levels and NASA TLX mental workloads calculated for all operations are shown in Table 4.10.

For the purpose of the study, the relationship between the changes in the mental load levels found by NASA TLX method due to the changes in risk levels found in REBA, RULA and NIOSH Lifting Equation methods was investigated by multiple regression analysis for the cause-effect relationship between the variables. The software was used for multiple regression analysis. After entering the data in Table 4.10 to the software program, the data used as a result of the NASA TLX method were defined as dependent variables, while the data used as a result of REBA, RULA and NIOSH methods were defined as independent variables.

As a result of the regression analysis performed in SPSS program, there was a significant relationship between mental workload and REBA risk level and NIOSH risk level, while there was no significant relationship between mental workload and RULA and NIOSH Lifting Equation risk levels. Mainly, the increase in the difficulties of the body postures which cover the entire body of the employees increases the mental workload level of the employees. In addition, it has been demonstrated that increases and decreases in the risk levels of lifting or lowering tasks affect the mental workload of the employees.

The study shows that employees' working postures and load lifting risk levels affect employees mentally. Work postures are important in the protection of employee health

in the short and long terms, increasing workplace and employee productivity, and eliminating employees from problems within the scope of cognitive ergonomics such as stress. Additionally, it is understood that, when assigning workers to jobs where work postures are more difficult or where lifting or lowering task is dominant, it is necessary to assign employees according to their abilities to cope with mentally challenging difficulties.

In further studies, the effect of working postures on mental workload can be measured by using different work posture methods and other subjective mental workload methods. Furthermore, an integrated risk level approach can be determined by calculating the mental workload and working postures and integrating them with multiple criteria decision making methods.

REFERENCES

[1] Meister, D. The History of Human Factors and Ergonomics, Taylor and Francis (1st Edition), Boca Raton, 2018

[2] History of Ergonomics, Retrieved September 8, 2019, from https://ergoweb.com/history-of-ergonomics/

[3] Ergonomi nedir?, Retrieved December 23, 2019, from https://www.isgnedir.com/ergonomi-nedir/

[4] Felekoğlu, B., & Taşan, S.Ö. Ergonomic risk assessment for work-related musculoskeletal disorders: A systematic reactive / proactive integrated approach. Journal of Gazı University Faculty of Engineering and Architecture, 32.3, 777-793, 2017.

[5] Kahya,E., et al. Ergonomic risk analysis in a metal industry operation. Journal of Engineering Sciences and Design, vol. 6, pp. 159–175, 2018.

[6] Can, G.F., Fıglalı, N. Image processing based rapid upper limb assessment method. Journal of the Faculty of Engineering and Architecture of Gazi University, 32.3: 719-731, 2017.

[7] Kırcı, B. K. Lojistik depo sektöründe reba, rula ve niosh yöntemleri ile ergonomi alaninda bir irdeleme. Master's thesis, University of Üsküdar. 2018

[8] Ali, A., et al. An ergonomic study of work related musculoskeletal disorders among the workers working in typical Indian saw mills. International Journal of Engineering Research and Development, 3.9: 38-45, 2012.

[9] Sahu, S., et al. A comparative ergonomics postural assessment of potters and sculptors in the unorganized sector in West Bengal, India. International Journal of Occupational Safety and Ergonomics, 19.3: 455-462, 2013.

[10] Kim, T., & Roh, H., Analysis of risk factors for work-related musculoskeletal disorders in radiological technologists. Journal of physical therapy science, 26.9: 1423-1428, 2014.

[11] Coşkun, M., et al. Defining the ergonomic risk of work stations via NIOSH method. Journal of Engineering Sciences and Design (JESD), 3.3: 365-370, 2015.

[12] Thetkathuek, A., et al. Factors affecting the musculoskeletal disorders of workers in the frozen food manufacturing factories in Thailand. International Journal of Occupational Safety and Ergonomics, 22.1: 49-56, 2016.

[13] Fazı, H. M., et al. Ergonomics study for workers at food production industry. InMATEC Web of Conferences, EDP Sciences, Vol. 90, p. 01003, 2017.

[14] Boulila, A., et al. Ergonomics study and analysis of workstations in Tunisian mechanical manufacturing. Human Factors and Ergonomics in Manufacturing & Service Industries, 28.4: 166-185, 2018.

[15] Rizkya, I., et al. Evaluation of work posture and quantification of fatigue by rapid entire body assessment (REBA). IOP Conference Series: Materials Science and Engineering. IOP Publishing. p. 012051, 2018.

[16] Yadi, Y. H., et al. Ergonomics Intervention Study of the RULA/REBA Method in Chemical Industries for MSDs' Risk Assessment. KnE Life Sciences, 4.5: 181-189, 2018.

[17] Kathiravan, S. & Gunarani, G. I., Ergonomic performance assessment (EPA) using RULA and REBA for residential construction in Tamil Nadu. International Journal of Civil Engineering and Technology, 9.4: 836-843, 2018.

[18] Micheletti Cremasco, M., et al., Risk assessment for musculoskeletal disorders in forestry: a comparison between RULA and REBA in the manual feeding of a wood-chipper. International journal of environmental research and public health, 16.5: 793, 2019.

[19] Julianus, H., Work posture analysis by using rapid upper limb assessment (RULA) and rapid entire body assessment (REBA) methods (case study: rice milling in malang-east java of Indonesia).IOP Conference Series: Materials Science and Engineering. IOP Publishing, p. 012012, 2019.

[20] Kulkarni, V. S., & Devalkar, R. V. Postural analysis of building construction workers using ergonomics. International Journal of Construction Management, 19.6: 464-471, 2019.

[21] Nagaraj, T., et al. Evaluation of ergonomic working conditions among standing sewing machine operators in Sri Lanka. International Journal of Industrial Ergonomics, 2019, 70: 70-83.

[22] Mahmood, S., et al. Posture assessment for workers repetitive tasks at poultry feed manufacturing industry. Science Proceedings Series, 1.2: 28-31, 2019.

[23] Manjunath, K. V. An Analysis of Work-Related Muscular-Skeletal Disorders among Employees in Garment Industry. VTU Journal of Engineering Sciences and Management, 1.2: 60-64, 2019.

[24] Rubio, S., et al. Evaluation of subjective mental workload: A comparison of SWAT, NASA-TLX, and workload profile methods. Applied Psychology, 53.1: 61-86, 2004.

[25] Yurko, Y.Y., et al. Higher mental workload is associated with poorer laparoscopic performance as measured by the NASA-TLX tool. Simulation in healthcare, 5.5: 267-271, 2010.

[26] Yiyuan, Z., et al. Using NASA-TLX to evaluate the flight deck design in Design Phase of Aircraft. Procedia Engineering, 17: 77-83, 2011.

[27] Gülkaç, H., Pilotlarin zihinsel iş yüklerinin nasa-tlx yöntemiyle ölçülmesi, Master's thesis, University of Kocaeli, 2013.

[28] Seker, A. Using outputs of NASA-TLX for building a mental workload expert system. Gazi University Journal of Science, 27.4: 1131-1142, 2014.

[29] Karadağ, M., & Cankul, I.The Evaluation of Mental Workload in Nurses" Journal of Anatolian Nursing and Health Sciences, 18.1, 2015.

[30] Delice, E. Evaluation of emergency service doctors' mental workload through NASA-RTLX method: an application study., 30.3, 2016.

[31] Rahman, N. I. et al. Subjective responses of mental workload during real time driving: A pilot Experimental Study. In: IOP Conference Series: Materials Science and Engineering. IOP Publishing, p. 012076, 2017.

[32] Delice, E., & Can, G. F. An integrated mental workload assessment approach based on NASA-TLX and SMAA-2: a case study. Journal of Engineering and Architecture Faculty of Eskişehir Osmangazi University, 26.2: 88-99, 2018.

[33] Emeç, S,. & Akkaya, G. Evaluation of mental work on the health sector and an application. Ergonomi, 1.3: 156-162, 2018.

[34] Dağdeviren, M., et al. Çalişanlarin toplam iş yükü seviyelerinin belirlenmesine yönelik bir model ve uygulamasi. Gazi Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi, 20.4., 2005.

[35] Ekinci, B., et al., "Algilanan iş yükü ve çalişma duruşlari dikkate alinarak operatörlerin ergonomik risk düzeylerinin çok kriterli karar verme yaklaşimi ile değerlendirilmesi" Ergonomi, 1.2: 77-91,2019.

[36] Yener, Y., et al. A job rotation proposal considering physical strain and perceived workload level. Journal of Engineering and Architecture Faculty of Eskişehir Osmangazi University, 27.1: 9-20, 2019.

[37] Ansari, N. A., et al. Study and justification of body postures of workers working in SSI by using REBA. International Journal of Engineering and Advanced Technology (IJEAT) Vol, 2.3, 2013.

[38] Baykent, G.; Çetinkayaa, F. İşyeri Çalışma Ortamı Koşullarının Ergonomik Yönden İncelenmesi (Örnek: Şekerleme Firması). Uşak Üniversitesi Fen ve

Doğa Bilimleri Dergisi, 1.1: 15-31, 2017.

[39] Neşeli, C., Ergonomik risk analizi yöntemlerinin karşilaştirilmasi ve bir kalip imalat firmasinda uygulanmasi. Master's thesis. University of Izmir Kâtip Çelebi, 2016.

[40] Özoğul, B., et al. Ergonomic risk analysis in a metal industry operation. Journal of Engineering Sciences and Design (JESD), 6: 159-175, 2018.

[41] Understanding the Different Types of Ergonomics. Retrieved December 23, 2019, from http://www.khmedia.in/understanding-the-different-types-of-ergonomics.html.

[42] Durmaz. G.,Ergonomi konunun genel amaci katilimcilarin, ergonomi ve iş fizyolojisi konusunda temel kavramlari bilmelerini ve işyerinde ergonomik düzenlemeler ve çalişma. Retrieved July 18, 2019, from https://slideplayer.biz.tr/slide/6029564/ .

[43] Ergonomi Çeşitleri, . Retrieved July 17, 2019, from https://ergoo018.wordpress.com/ergonomi-cesitleri/.

[44] Çakmak, E., Risk Değerlendirmesi - Temel Sunum. Retrieved July 10, from https://www.slideshare.net/ekremcakmak/ekrem-akmak-risk-deerlendirmesi. Nov 27, 2013.

[45] Gürleyen, E., & Kahya, E., "The ergonomic risk analysis with reba method in combination assembly." Journal of Engineering Sciences and Design (JESD), 6: 58-66, 2018.

[46] Çiçek, E., et al. "The ergonomic risk analysis in a asssembly line of furniture company Journal of Engineering Sciences and Design (JESD), 6: 67-82,2018.

[47] Ansari, N. A., & Sheikh, M. J., Evaluation of work Posture by RULA and REBA: A Case Study.IOSR Journal of Mechanical and Civil Engineering. 11.4: 18-23, 2014.

[48] Moradi, M., et al. REBA method for the ergonomic risk assessment of auto mechanics postural stress caused by working conditions in Kermanshah (Iran). Annals of Tropical Medicine and Public Health, 10.3: 589, 2017.

[49] Öngel, K., et al. Application of ergonomic risk analysis methods in a mold manufacturing period and regulatory recommendations. Smyrna Medical Journal,44, 2017.

[50] Djiono, Y. K., & Noya, S. Working Posture Analysis And Design Using RULA (Rapid Upper Limb Assessment) Method In Production Process. At PT. Indana Paint. 2013.

[51] Rapid Upper Limb Assessment (RULA), Retrieved September 18, 2019, from https://www.coreconcepts.com.sg/article/rapid-upper-limb-assessment-RULA/.

[52] Akkale, E. C. Elle taşima işlerinde iş sağliği ve güvenliğinin niosh kaldirma denklemi ile incelenmesi. T.C.ÇALIŞMA VE SOSYAL GÜVENLİK BAKANLIĞI İş Teftiş Kurulu Başkanlığı İş Müfettişi Yardımcılığı Etüdü,2014.

[53] Dempsey, P. G. Usability of the revised NIOSH lifting equation. Ergonomics, 45.12: 817-828, 2002.

[54] Waters, T. R., & et al. Accuracy of measurements for the revised NIOSH lifting equation. Applied Ergonomics, 29.6: 433-438, 1998.

[55] What do you have to know to calculate the recommended weight limit (RWL)?, Retrieved December 20, 2019, from https://www.ccohs.ca/oshanswers/ergonomics/niosh/assessing.html.

[56] Work-related Musculoskeletal Disorders (WMSDs), Retrieved December 20, 2019, from https://www.ccohs.ca/oshanswers/diseases/rmirsi.html.

[57] De Quervain tendiniti nedir?, Retrieved December 20, 2019, from https://www.florence.com.tr/de-quervain-tendiniti-nedir.

[58] Cain, B. A review of the mental workload literature. Defence Research And Development Toronto (Canada), 2007.

APPENDICES

Appendix-A REBA Worksheet

Appendix-B RULA Worksheet

Appendix-C NIOSH Measurement Materials and Tables

Appendix-D The Questionnaire for NASA-TLX

Appendix-E ErgoFellow 3.0 Software Images

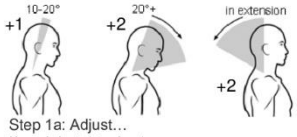
ERGONOMICS PLUS

REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

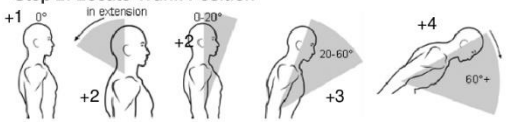
Step 1: Locate Neck Position



Neck Score

Step 1a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

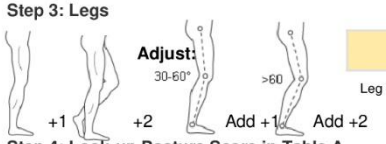
Step 2: Locate Trunk Position



Step 2a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 3: Legs



Leg Score

Step 4: Look-up Posture Score in Table A

Using values from steps 1-3 above,
Locate score in Table A

Posture Score A

Step 5: Add Force/Load Score

If load < 11 lbs. : +0
If load 11 to 22 lbs. : +1
If load > 22 lbs.: +2

Adjust: If shock or rapid build up of force: add +1 Force / Load Score

Step 6: Score A, Find Row in Table C

Add values from steps 4 & 5 to obtain Score A.
Find Row in **Table C**.

Score A

Scoring
1 = Negligible Risk
2-3 = Low Risk. Change may be needed.
4-7 = Medium Risk. Further Investigate. Change Soon.
8-10 = High Risk. Investigate and Implement Change
11+ = Very High Risk. Implement Change

Scores

Table A		Neck											
		1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

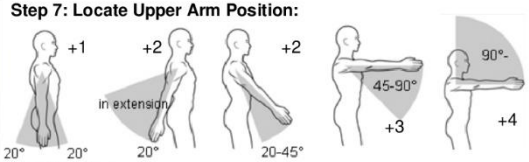
Table B		Lower Arm					
		1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

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

Table C Score + Activity Score = REBA Score

B. Arm and Wrist Analysis

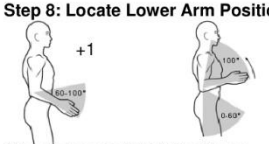
Step 7: Locate Upper Arm Position:



Step 7a: Adjust…
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 8: Locate Lower Arm Position:



Lower Arm Score

Step 9: Locate Wrist Position:



Wrist Score

Step 9a: Adjust…
If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B

Using values from steps 7-9 above, locate score in Table B

Posture Score B

Step 11: Add Coupling 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

Coupling Score

Step 12: Score B, Find Column in Table C

Add values from steps 10 &11 to obtain Score B. Find column in **Table C** and match with Score A in row from step 6 to obtain Table C Score.

Score B

Step 13: Activity Score

+1 1 or more body parts are held for longer than 1 minute (static)

+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Original Worksheet Developed by Dr. Alan Hedge. Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

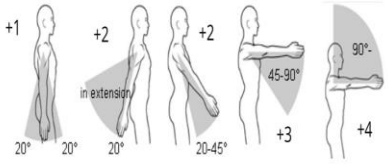
Appendix B: RULA Worksheet

ERGONOMICS PLUS

RULA Employee Assessment Worksheet Task Name: Date:

A. Arm and Wrist Analysis

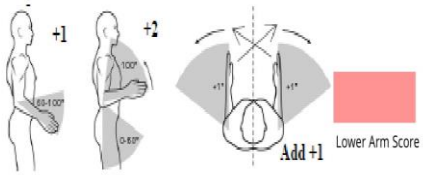
Step 1: Locate Upper Arm Position:



Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

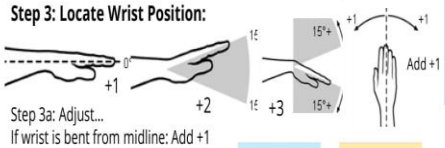
Step 2: Locate Lower Arm Position:



Lower Arm Score

Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:



Step 3a: Adjust...
If wrist is bent from midline: Add +1

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Wrist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A

+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 7: Add Force/Load Score
If load < .4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in **Table C**.

Wrist & Arm Score

Scores

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

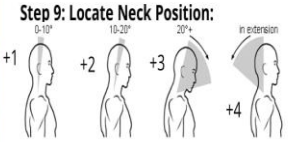
Table C		Neck, Trunk, Leg Score						
		1	2	3	4	5	6	7+
Wrist / Arm Score	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

RULA Score

B. Neck, Trunk and Leg Analysis

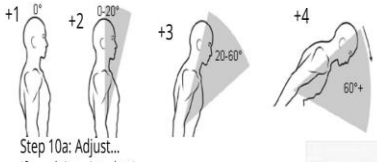
Step 9: Locate Neck Position:



Neck Score

Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:



Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Table B: Trunk Posture Score												
Neck Posture Score	1		2		3		4		5		6	
	Legs		Legs		Legs		Legs		Legs		Legs	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above, locate score in Table B

Posture B Score

+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 14: Add Force/Load Score
If load < .4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in **Table C**.

Neck, Trunk, Leg Score

Original Worksheet Developed by Dr. Alan Hedge. Based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99

Appendix C: NIOSH Measurement Materials and Tables

LIFTING ANALYSIS WORKSHEET

DEPARTMENT _____ JOB DESCRIPTION

JOB TITLE _____ _____

ANALYST'S NAME _____ _____

DATE

STEP 1. Measure and record task variables

Object Weight (lbs)		Hand Location				Vertical Distance	Asymmetric Angle (deg.)		Frequency Rate	Duration	Object Coupling
		Origin		Dest			Origin	Destination	lifts/min	Hrs	
L(AVG)	L(MAX)	H	V	H	V	D	A	A	F		C

STEP 2. Determine the multipliers and compute the RWLs

RWL = LC xHM xVM x DMxAM x FMx CM

ORIGIN	RWL	=	51	x		x		x		x		x		x		~	
DEST.	RWL	=	51	x		x		x		x		x		x		~	

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFT INDEX $\frac{\text{OBJECT WEIGHT}}{\text{RWL}}$ = _____ = _____

DESTINATION LIFT INDEX $\frac{\text{OBJECT WEIGHT}}{\text{RWL}}$ = _____ = _____

Figure C.1.NIOSH Job Analysis Worksheet

Table.C.1. Horizontal Multiplier Table

H	**HM**	**H**	**HM**
in		cm	
≤ 10	1.00	≤ 25	1.00
11	.91	28	.89
12	.83	30	.83
13	.77	32	.78
14	.71	34	.74
15	.67	36	.69
16	.63	38	.66
17	.59	40	.63
18	.56	42	.60
19	.53	44	.57
20	.50	46	.54
21	.48	48	.52
22	.46	50	.50
23	.44	52	.48
24	.42	54	.46
25	.40	56	.45
> 25	.00	58	.43
		60	.42
		63	.40
		> 63	.00

Table.C.2. Vertical Multiplier Table

V	**VM**	**V**	**VM**
in		cm	
0	.78	0	.78
5	.81	10	.81
10	.85	20	.84
15	.89	30	.87
20	.93	40	.90
25	.96	50	.93
30	1.00	60	.96
35	.96	70	.99
40	.93	80	.99
45	.89	90	.96
50	.85	100	.93
55	.81	110	.90
60	.78	120	.87
65	.74	130	.84
70	.70	140	.81
>70	.00	150	.78
		160	.75
		170	.72
		175	.70
		>175	.00

Table.C.3. Distance Multiplier Table

D	DM	D	DM
in		cm	
≤10	1.00	≤25	1.00
15	.94	40	.93
20	.91	55	.90
25	.89	70	.88
30	.88	85	.87
35	.87	100	.87
40	.87	115	.86
45	.86	130	.86
50	.86	145	.85
55	.85	160	.85
60	.85	175	.85
70	.85	>175	.00
>70	.00		

Table C.4. Asymmetric Multiplier Table

A	**AM**
deg	
0	1.00
15	.95
30	.90
45	.86
60	.81
75	.76
90	.71
105	.66
120	.62
135	.57
>135	.00

Table.C.5. Frequency Multiplier Table

Frequency Lifts/min (F) ‡	**Work Duration**					
	≤ 1 Hour		**> 1 but ≤ 2 Hours**		**> 2 but ≤ 8 Hours**	
	V<30†	V≥30	V<30	V≥30	V<30	V≥30
≤ 0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
> 15	.00	.00	.00	.00	.00	.00

Appendix D: The Questionnaire for NASA-TLX

İŞ YÜKÜ ANKETİ

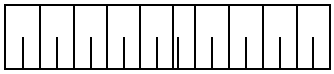
Lütfen size uygun cevabı işaretleyiniz.

KİŞİSEL BİLGİLER						
1	**Cinsiyetiniz**	Erkek ( )	Kadın ( )			
2	**Medeni Durumunuz**	Evli ( )	Bekar ( )			
3	**Yaşınız**	18-24 ( )	25-31 ( )	32-38 ( )	39-45 ( )	46 ve Üstü ( )
4	**Öğrenim Durumunuz**	Herhangi bir öğretim kurumundan mezun değilim ( )	İlköğretim ( )	Lise ( )	Yüksekokul ( )	Üniversite ( )
5	**Toplam Çalışma Yılınız**	1 yıldan az ( )	1-3 ( )	4-6 ( )	7-10 ( )	10 yıldan fazla ( )
6	**Panagro Et & Süt Entegre Tesisi'nde Toplam Çalışma Yılınız**	1 yıldan az ( )	1-3 ( )	3-6 ( )	7-10 ( )	10 yıldan fazla ( )
7	**İşyerinizden memnun musunuz?**	Çok memnunum ( )	Memnunum ( )	Memnun değilim ( )	Hiç memnun değilim ( )	
8	**Çalıştığınız Birim/Bölüm**					

İş yükü anketi - Bölüm 1

Aşağıdaki 6 faktöre ait ölçeklerin her birinde, verilen görevi yaparken hissettiklerinizin derecesini işaretleyiniz

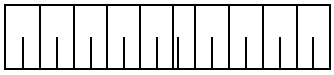
ZİHİNSEL ZORLANMA



AZ ÇOK

Verilen görevi tamamlamak için zihinsel olarak ne kadar zorlandınız (örneğin düşünürken, araştırma yaparken, karar verirken, hesaplarken, hatırlarken, vb)?

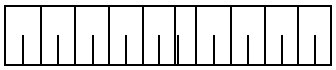
FİZİKSEL ZORLANMA



AZ ÇOK

Verilen görevi tamamlamak için fiziksel olarak ne kadar zorlandınız (örneğin iterken, çekerken, döndürürken, kontrol ederken, çalıştırırken vb)?

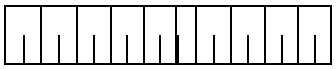
ZAMAN GEREKSİNİMİ



AZ ÇOK

Verilen görevi tamamlamak için ne kadar zamana ihtiyaç duydunuz? Verilen zaman az mıydı, yeterli miydi? Görevi tamamlamak için yavaş ve sakin mi çalıştınız (AZ), hızlı ve aceleyle mi çalıştınız (ÇOK)?

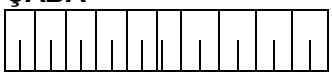
PERFORMANS



İYİ KÖTÜ

Verilen görevin amacına ulaşmak için gösterdiğiniz performansı nasıl değerlendirirsiniz? Verilen görevi yerine getirip getirmediğiniz konusunda kendinizi ne kadar başarılı buluyorsunuz?

ÇABA



AZ ÇOK

Kendi performans düzeyinize ulaşmak için hem zihinsel, hem de fiziksel olarak ne kadar çaba gösterdiniz? Ne kadar çalışmak zorunda kaldınız?

HAYAL KIRIKLIĞI



AZ ÇOK

Verilen görevi yerine getirirken ne kadar hayal kırıklığı hissettiniz? Ne kadar umutsuzluğa kapıldınız? Kendinizi ne kadar güvensiz, bezgin, rahatsız, stresli, sinirli hissettiniz?

İş yükü anketi - Bölüm 2

Bundan sonraki 15 soruda, size verilen görevi 2 açıdan karşılaştırın. İki seçenekten hangisinin iş yükünüze daha çok etki ettiğini düşünüyorsanız onu işaretleyiniz.

1. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
   A) PERFORMANS **B) ZİHİNSEL ZORLANMA**
2. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
   A) ÇABA **B) PERFORMANS**
3. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
   A) PERFORMANS **B) HAYAL KIRIKLIĞI**
4. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
   A) HAYAL KIRIKLIĞI **B) ZİHİNSEL ZORLANMA**
5. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
   A) FİZİKSEL ZORLANMA **B) ZAMAN GEREKSİNİMİ**
6. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
   A) ZAMAN GEREKSİNİMİ **B) ÇABA**
7. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
   A) ZAMAN GEREKSİNİMİ **B) HAYAL KIRIKLIĞI**
8. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
   A) ZAMAN GEREKSİNİMİ **B) ZİHİNSEL ZORLANMA**
9. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
   A) ZİHİNSEL ZORLANMA **B) ÇABA**

10. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
A) PERFORMANS **B) ZAMAN GEREKSİNİMİ**

11. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
A) ÇABA **B) FİZİKSEL ZORLANMA**

12. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
A) FİZİKSEL ZORLANMA **B) PERFORMANS**

13. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
A) ZİHİNSEL ZORLANMA **B) FİZİKSEL ZORLANMA**

14. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
A) HAYAL KIRIKLIĞI **B) ÇABA**

15. Aşağıdaki iki faktörden hangisinin iş yükünüz üzerindeki etkisi daha fazlaydı?
A) FİZİKSEL ZORLANMA **B) HAYAL KIRIKLIĞI**

ÇALIŞMA ORTAMINIZIN SAĞLIĞINIZI ETKİLEDİĞİNİ DÜŞÜNÜYOR MUSUNUZ? ETKİLEDİĞİNİ DÜŞÜNÜYORSANIZ LÜTFEN NEDENLERİNİ AÇIKLAYINIZ.

FİZİKSEL OLARAK İŞ YÜKÜNÜZÜN ÇOK OLDUĞUNU DÜŞÜNÜYORSANIZ LÜTFEN ÇALIŞTIĞINIZ BÖLÜMÜ VE GÖREVİNİZİ YAZINIZ:

Appendix E: ErgoFellow 3.0 Software Images

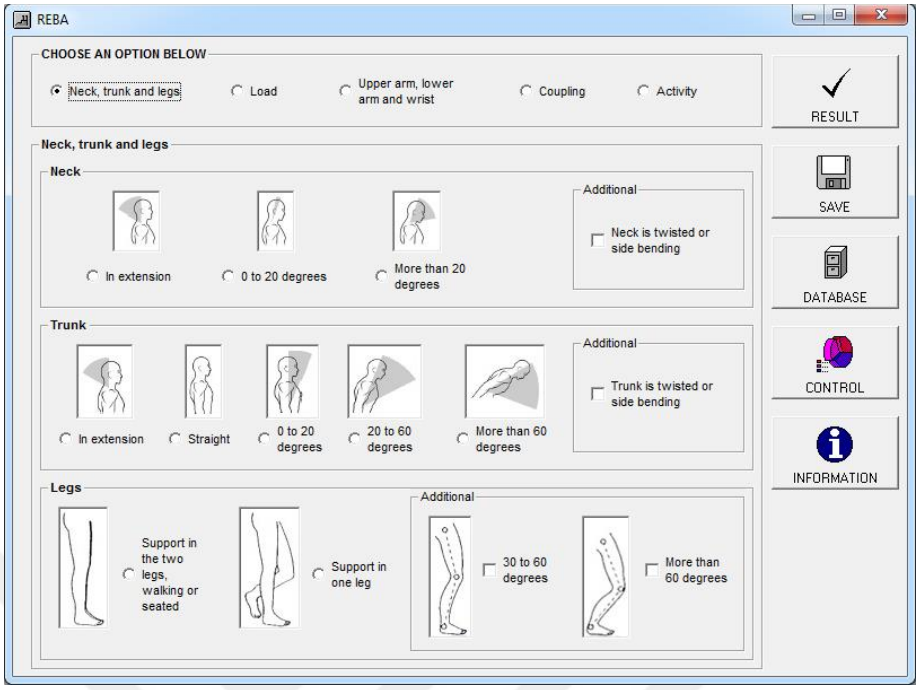


Figure E.1. ErgoFellow3.0 software REBA tool

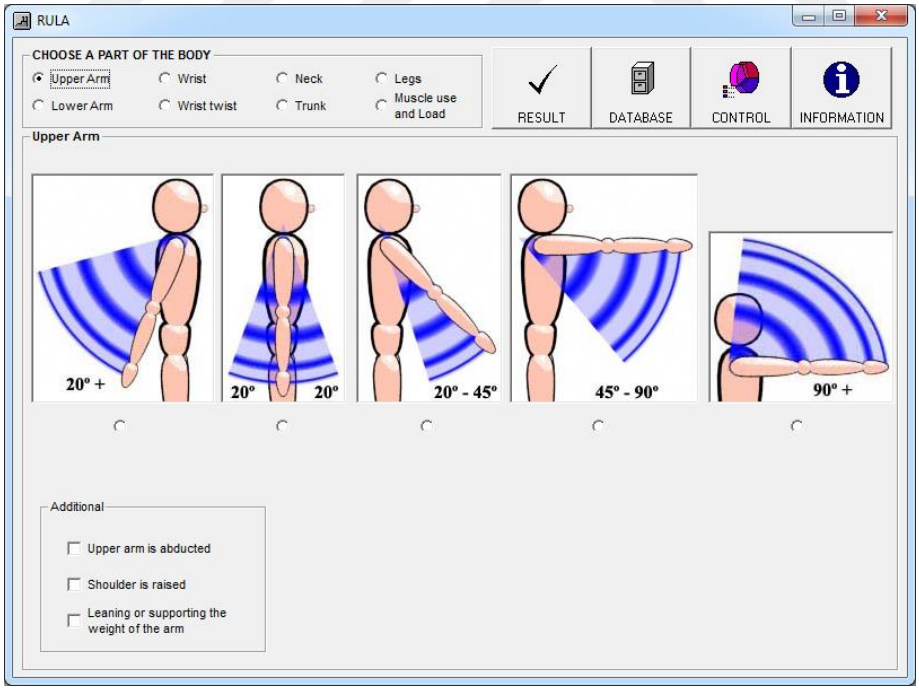


Figure E.2. ErgoFellow software RULA tool

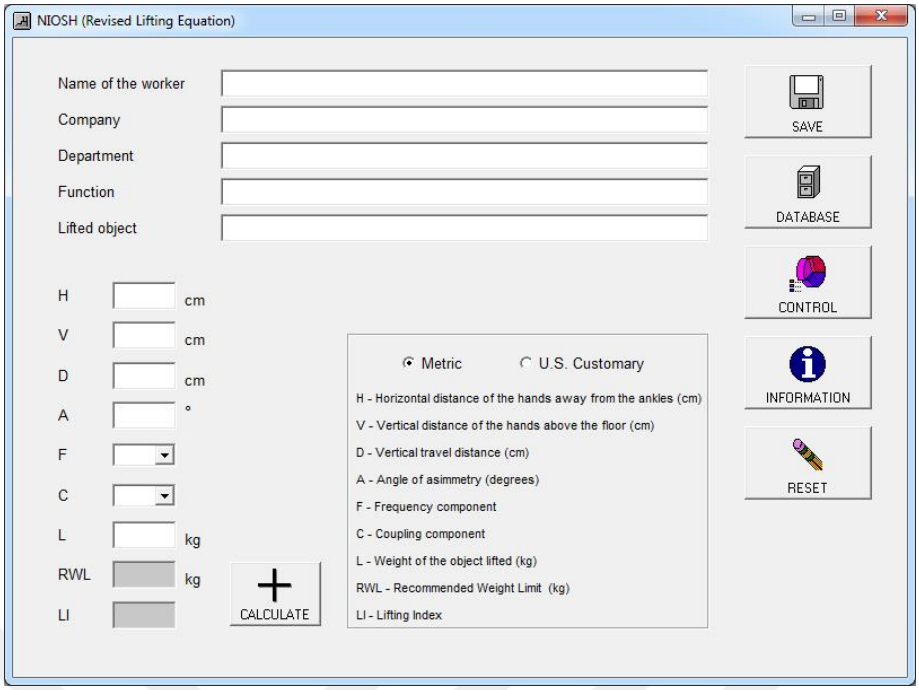


Figure E.2. ErgoFellow 3.0 software NIOSH tool

CURRICULUM VITAE



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Master Degree : Ankara Yıldırım Beyazıt University (2017-2020)

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Research Assist. : Konya Food&Agriculture University (2018-…)

TOPICS OF INTEREST

Systems Engineering

Multi-Criteria Decision Making

Human Factors and Ergonomics

Production Planning and Scheduling

PUBLICATIONS/PRESENTATIONS

*12th New Challenges in Management and Business Conference ‘A Turn-Key Project Design Using Structured Systems Engineering Techniques: Vermicomposting’

* 12th New Challenges in Management and Business Conference “Set Covering and Maximum Covering Models for Location Selection and Resource Allocation: Case Study in Turkey”

*11th New Challenges in Management and Business Conference ‘Comparison of Fuzzy AHP and Fuzzy TOPSIS Methods for Municipal Services Evaluation’

* 10th International Statistics Congress – ‘Evaluation of Municipal Services with Fuzzy Analytic Hierarchy Process for Local Elections’

PUBLICATIONS/PRESENTATIONS DERIVED FROM THESIS

*4th International Congress on Engineering, Architecture and Design *"Ergonomic Risk Evaluation in A Factory: Case Study In Konya"* Şeyma Özdoğan, Ergün Eraslan, D.Tayyar Şen.