REPUBLIC OF TURKEY

ADANA ALPARSLAN TÜRKEŞ SCIENCE AND TECHNOLOGY UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

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DIGITAL HUMAN MODELING APPLICATIONS IN PRODUCT DESIGN AND WORKPLACE DESIGN

FATİH AKBAŞ

MASTER OF SCIENCE

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SUPERVISOR

Assoc. Prof. Dr.MUSTAFA GÖÇKEN

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I hereby declare that all information in this thesis has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all information that is not original to this work.

[Signature]

Fatih AKBAŞ

ABSTRACT

DIGITAL HUMAN MODELING APPLICATIONS IN PRODUCT DESIGN AND WORKPLACE DESIGN

Fatih AKBAŞ
Department of Industrial Engineering
Supervisor: Assoc. Prof. Dr. Mustafa GÖÇKEN

September 2019, 63 pages

Nowadays, people have started to need more comfortable products and comfortable working environments. People's quest for comfort led to the development of ergonomic designs. Thanks this developments, digital human modeling method have began to develop. Accordingly, many digital human modeling studies have been done to fulfill this necessity mentioned above. These digital human models have not only improved comfort but at the same time, it enabled other human and product factors such as cost, design time, dimensions, and more to reach the optimum level.

The aim of this study is to analyze the ergonomic status of the different chairs used in the offices with digital human modeling method and to interpret the results. This study was considered appropriate due to the increase in the incidence of work-related musculoskeletal disorders. The NIOSH standards pre-embedded in the Jack software, were evaluated and compared the result with respect to BIFMA limits. Thus, It was observed whether the model used is ergonomic or not.

The study of digital human modeling have been carried out in an office to reduce the risks by considering incidence metioned before. Softwares and hardwares have been utilized in this study such as Kinect technology, a Microsoft product, which integrated with the JACK software for analyzing. Observations and results showed that DHM programs have the potential of developing the ergonomic products.

Keywords: digital human modeling, human factors and ergonomics, product lifecycle management, simulation & modeling, jack, kinect

ÖZET

İŞ YERİ VE ÜRÜN TASARIMINDA DİJİTAL İNSAN MODELLEME UYGULAMALARI

Fatih AKBAŞ
Endüstri Mühendisliği Anabilim Dalı
Danışman: Doç. Dr. Mustafa GÖÇKEN
Eylül 2019, 63 sayfa

Günümüzde insanlar daha konforlu ürünlere ve konforlu çalışma ortamlarına ihtiyaç duymaya başladılar. İnsanların konfor arayışı ergonomik tasarımların geliştirilmesine yön verdi. Bu gelişimle birlikte dijital insan modelleme yöntemi gelişim göstermeye başladı. Birçok dijital insan modelleme çalışmaları yapıldı. Bu dijital insan modeller sadece konforu arttırmadı. Aynı zamanda, diğer insan ve ürün faktörlerinin (maliyet, tasarım süresi, boyutlar vb.) optimum seviyelere ulaşmasını sağladı.

Bu çalışmanın amacı, günümüzde ofislerde kullanılan farklı sandalyelerinin ergonomik durumunu dijital insan modelleme methoduyla analiz etmek ve sonuçlarını yorumlamaktır. İşe bağlı kas-iskelet sistemi rahatsızlıklarının görülme sıklığının artışından dolayı böyle bir çalışma uygun görüldü. Jack programı içine gömülü olan NIOSH kriterleri değerlendirilip BIFMA limitleriyle karşılaştırılmıştır. Kullanılan modelin ergonomik olup olmadığı gözlemlenmiştir.

Bu bozuklukları göz önünde bulundurarak riskleri azaltmak için dijital bir insan modelleme çalışması yapılmıştır. Bu çalışma yapılırken bazı yazılım ve donanımlar kullanıldı. Microsoft ürünü olan Kinect teknolojisi, JACK yazılımıyla entegre edildi ve analizler yapıldı. Gözlemler ve sonuçlar, DHM programlarının ergonomik ürün geliştirme potansiyeline sahip olduğunu göstermiştir.

Anahtar Kelimeler: dijital insan modelleme, insan faktörleri ve ergonomi, ürün yaşam döngüsü yönetimi, simülasyon ve modelleme, jack, kinect

To my wife , my family and Nicola Tesla …

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Fatih AKBAŞ

Industrial Engineer

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NOMENCLATURE

DHM	: Digital Human Modeling
CAD	: Computer Aided Design
CAE	: Computer Aided Engineering
PLM	: Product Lifecycle Management
WMSD	: Work-related Musculoskeletal Disorders
2D	: 2 dimension
3D	: 3 Dimension
NASA	: National Aeronautics and Space Administration
OPT	: Occupant Packaging Toolkit
TAT	: Task Analysis Toolkit
CAESAR	: Civilian American And European Surface Anthropometry Resource
US	: Ultrasound System
RGB	: Red,Green and Blue Camera
SEC	: Second
KHZ	: Kilohertz
BIT	: Byte
SDK	: Software Development Kit
PC	: Personel Computer
USB	: Universal Serial Bus
NIOSH	: National Institute for Occupational Safety And Health
BIFMA	: Business and Institutional Furniture Manufacturers Association

1. INTRODUCTION

The changes are observed in every field all around the world and they are forcing the people working in these areas mentally and physically. Inherently, people have to keep their occupational health and safety within all economic fields and in industry by adopting the changes.

For all of clear reasons, people want minimizations of occupational accidents or illnesses. As a result of these developments and concerns, a new branch of science emerged which is called Ergonomics. It concerns with the evaluation of humans' capabilities such as working and environmental factors, physical and mental behaviours on the human body, fatigue, temperature etc. Ergonomics, which has been translated into our language as business science, includes methods and techniques for humanizing the work. When it is called humanization it should be understood that the work should be improved by taking the power and the needs of the employee into account.

Thus, ergonomics aims to preserve the health of the working person by minimizing the physical and/or mental burdens that the work creates on the human. Ergonomics, which tries to reveal the basic laws of system efficiency and employee-machine-environment harmonization, is also one of the compulsory trainings in the regulations issued about occupational health and safety in many countries.

1.1. History of Ergonomics

In the early 1900’s, the production of industry was still largely dependent on human power/motion and ergonomic concepts were developing to improve worker productivity. Scientific Management, a method that improved worker efficiency by improving the job process, became popular ("History of Ergonomics | Sustainable Ergonomics Systems", 2019).

Frederick W. Taylor was a pioneer of this approach and evaluated jobs to determine the “One Best Way” they could be performed. At Bethlehem Steel, Taylor dramatically increased worker production and wages in a shoveling task by matching the shovel with the type of material that was being moved (ashes, coal or ore) ("History of Ergonomics | Sustainable Ergonomics Systems", 2017).

During the World War II, complex military equipment have been started to use. The design of these complex equipment was quite challenging since the human-machine relationship began to increase too much. The human-machine relationship has become increasingly complex and new methods have emerged in the design of increasing equipment such as airplanes, tanks and other machines. These complex systems should also be useful and at the same time people using the machines should not be forced while using it.

For example, the buttons and control units should have to be reachable. The need for studies involving human modeling systems began to increase rapidly. It was necessary to take the physical and mental needs of human beings into account. All of this would naturally caused ergonomics to play an active role in our lives.

After World War II, work was expanded to increase workers' safety and productivity.
Studies have begun in the following various areas:

- Efficient use of muscle strength
- Waist force loads
- Cardiovascular conditions in heavy work
- Conditions during the transportation of maximum loads.

Cognitive ergonomics or human factors are a branch of science that examines human behavior and qualities. Knowledge areas are composed of decision making processes, organizational designs, human perceptions and intuitions. In addition, industrial ergonomics or ergonomics is a branch of science that examines the physical aspects of a workplace, vibration, light, force, and man-machine interactions. Therefore, ergonomics supports reaching the optimum values for human in all aspects.

It is a very important experience group in terms of enterprises to ensure work compliance and increase productivity. Experience is the community, because it is based on the human ergonomics; use humanities such as medicine, psychology and sociology. In addition to technical sciences such as physics, the economy is intertwined with social sciences such as law.

Some technological developments have occurred with the developing science of ergonomics. For example, some software and visual design tools have been developed for ergonomic designs. The processes in the production and life cycles of the products are examined. Digital modeling and computer aided design are beginning to emerge.

Since it is a human being in the center of ergonomics, it has been human centered in these models. Computer-aided new areas have emerged due to the goal of achieving ergonomic designs. There have been two new areas such as digital human modeling (DHM) and product life management (PLM). With the computer, much simpler human modeling has been started. More ergonomic designs and systems are being developed. Digital human modeling (DHM) plays an effective role in the automotive industry and workplace design (Hanson et al., 2009).

However, it is also observed that the cost reduction studies in health areas are used in the design processes. As seen in this study, DHM has really effective results not only in the industrial field but also in the healthcare.

1.2. Product Lifecycle Management (PLM)

PLM is the most effective way to manage and monitor a company's products throughout their entire life cycle. It is the process that lasts from the first idea of a product until it is disposed (Stark, 2015).

PLM's aim is to increase product incomes and quality, reduce product costs, expand product portfolio. PLM is an infinite process that continues until a product is removed from circulation. PLM also directs the portfolio of a company's entire products. Some companies make strategic plans and guide the PLM management of products. We can better examine where these plans are effective. The product’s life cycle consists of five main period:

Product development, Product introduction, Product growth, Product maturity and Product decline. Since the profit increase is the most important focus of a company, we can see the most important place in PLM from the figure 1.1 (Stark, 2015).

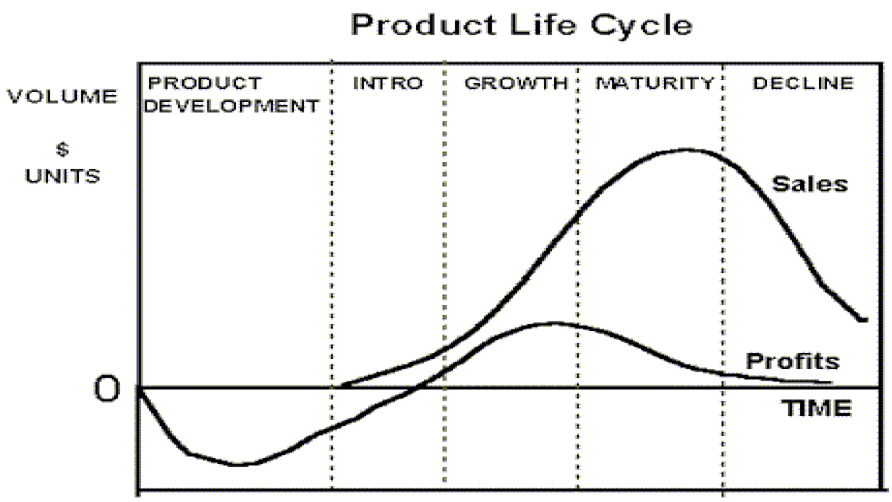

Figure 1.1 Product life cycle graph (Komninos, 2002)

During the PLM process, a number of computer aided software and hardware have been developed. These are sometimes human-centered models, while others are computer-aided drawing programs. In PLM, these programs and tools have led to new approaches such as digital human modeling. Approaches like DHM have emerged at the most strategic points of the companies.

1.3. Digital Human Modeling (DHM)

DHM uses digital humans as representations of the workers inserted into a simulation or virtual environment to facilitate the prediction of performance and/or safety. Also, it includes visualizations of the human with the math and science in the background. (Demirel & Duffy, 2009).

Digital Human Modeling (DHM) makes modeling that has been supported by mathematical calculations and allows us to achieve the best results by interpreting. These results have a potential of increasing profitability, comfortability and sometimes represents more useful models. DHM guides people with respect to product, service and space design.

Ford Motor Company used JACK human simulation to focus on ergonomic points and worker safety issues while developing an ergonomic, innovative satellite digital radio system. The design phase of the simulation process took place very quickly.

DHM is one of the most important point for PLM which plays an indispensable role that guides the PLM. DHM integration within PLM could be stated as vital point since this integration advances to produce more ergonomic designs if it done correctly, effectively and efficiently. If integration is healthy, the product efficiency and usefulness and cost are very well affected.

The effective integration of DHM and PLM tools ensures the control of the product's life cycle. The succesive integration starting from design development can prevent kinds of difficulties which can be come up until the product or service reaches the final consumer. This effective integration leads us not only in product development but in many other issues as well. With an effective integration; it is possible to save time, contribute to ergo- matic development, improve human-machine applications, increase performance and reduce costs.

One of the most important structure of DHMs is computer aided tools and software. Great results can be obtained with these tools. DHM tools are particularly useful for proactive ergonomics consideration in design processes where computer-aided design (CAD) tools are used to define products and workplaces and where no physical prototypes exist or are to be produced (e.g. due to cost or time) (Hanson & Högberg, 2012).

The Digital Human Modeling tools are consist of four main parts:

1- A digital model of man

2- A part of the equipment or environment of interaction;

3- Model posture or movement

4- Evaluation method

DHM tools are used to organize, design, visualize and analyze human workspaces. It is also used in the human-product relationship in the whole process prior to the design of the products. Simulations and visualizations are widely used since they play a major role in ergonomic formations and design development models.

Simulations and visualizations emphasize some ergonomic points. These points include areas of human position, human comfort, working space, tools, equipment and working areas (Hanson & Högberg, 2012).

There are a lot of digital human modeling systems such as ProAnalyst Professional, Visual3D Professional, MaxPRO, SAMMIE, JACK, RAMSIS. A popular digital human modeling based tool, JACK.

DHM tools have a myriad of benefits. Cost reduction, increasing efficiency, time saving, preventing mental disorders, preventing skeletal system discomfort and work accidents, reducing occupational diseases, workplace designs, new product designs are the examples of some of these benefits. The most important benefit is the development of ergonomic designs.

1.4. History of Digital Human Modeling (DHM)

In the early 1960s computer aided design (CAD) software became available, and aerospace and automotive manufacturers saw the potential for much of the design process to take place in a virtual environment. The development of CAD modeling software meant that designs could be created on a greatly reduced timescale, while at the same time allowing for the exploration of a wider range of design solutions. Recognising the potential to accelerate the design process and at the same time optimise the human machine interface, digital human modeling tools emerged in the late 1960s in the automotive and aviation industries (Blanchonette, 2010).

We see the defense industry, which is also effective in the birth of many disciplines, have leaded the birth of computer-aided and digital modeling systems. Computer-assisted and modeling systems which provide very efficient results in the time-saving and prototype production in the design process have undoubtedly continued to develop effectively over time. It is also could be noted that developments in the automotive and aerospace industry have led to the development of digital humanoid models.

The first human modeling design was made by Boeing Company in the mid-1900s. This model was reported as First Man. In order to design ergonomic living spaces in the cockpit of the aircraft by Boeing, the first model produced was the Boeman model.

The Boeman mannequin was designed based on a large database. Using this database, this mannequin is designed with 23 different joint points (shown the figure 1.2).

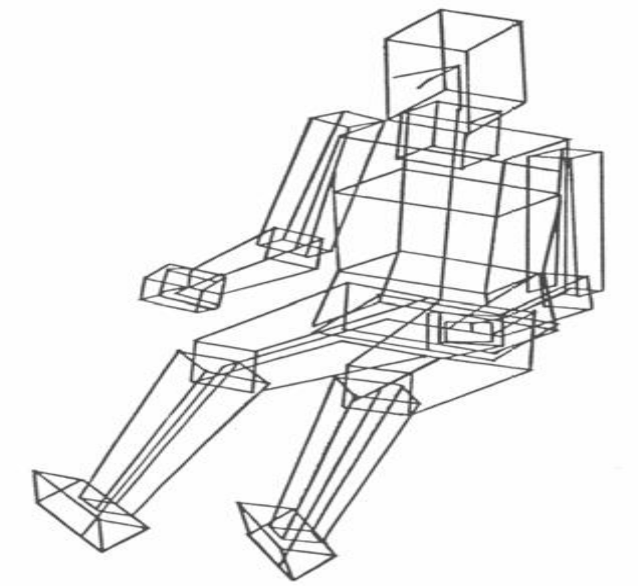

Figure 1.2. The Boeman model (Blanchonette, 2010)

In the years that followed, the Boeman Model gave direction to other studies. The Boeman Model has been further developed and paved the way for new models on military models. It has been a very important guide in the design and the development of military equipment and military aircraft.

The Boeman model was developed further for military aircraft design and evaluation and evolved into the Computerised Biomechanical Man Model (Combiman), shown the figure 1.3 (Blanchonette, 2010).

Dayton University developed Combian Moodel. Armstrong Aerospace Medical Research Laboratory tried to improve more. This model was created in a database. Many observations and designs can be made with this database.

Using Combiman, a mannequin could be created based on anthropometric data from six military databases. To support ergonomic analysis, Combiman can produce a field of view and determine the access of the pilot, by taking the effects of clothes and harnesses into account. To enhance the effect of ergonomic analysis, the Combian model can enhance the pilot's visibility and usefulness in the panel. At the same time, strength predictions can be analyzed using empirical data (Blanchonette, 2010).

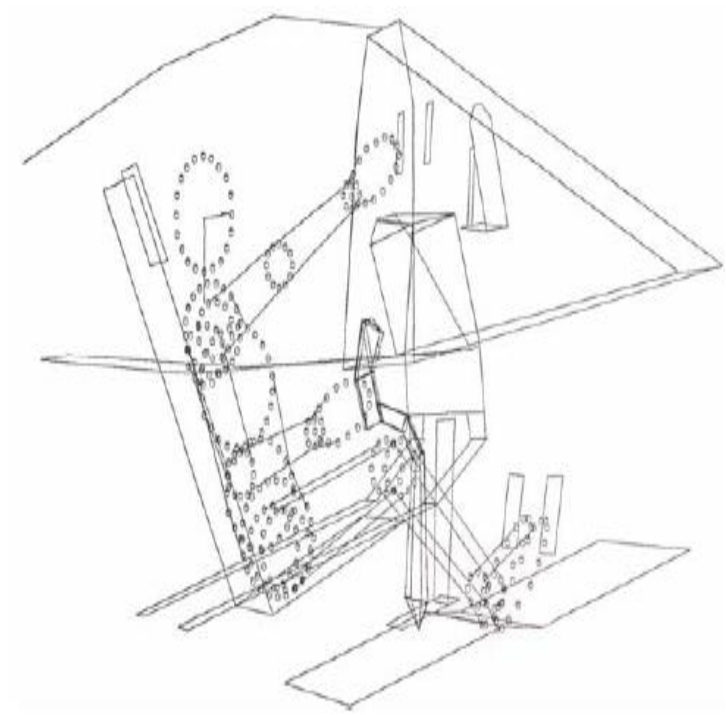

Figure 1.3. Combiman model (Blanchonette, 2010)

It can be stated that digital human modeling applications in military areas have started to affect other sectors too. By the 1970s, DHM modeling was started and developed in the automotive sector. Thusly a model called the Cyberman model emerged by Chrysler Corporation (shown in figure 1.4) Cyberman model cars are designed to make interior designs more ergonomic and convenient.

The mannequin was made up of 15 segments of any required size, but the mannequin did not have joint constraints, so care had to be taken when posing the mannequin (Blanchonette, 2010).

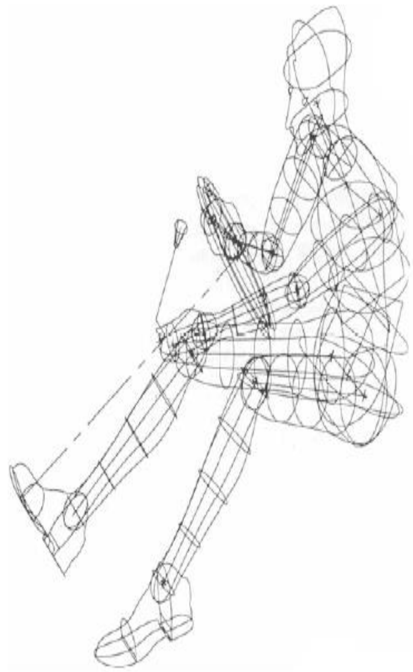

Figure 1.4. Cyberman model, by the Chrysler Corporation (Blanchonette, 2010)

Looking at the milestones of all these developments, the process which started in 2 dimensions as a model has started to take shape rapidly. This development has led to 3D models and even digital simulations. The process that started in the military field started to move towards every area and place where people are. Good results have been observed from the developments. But the results were sometimes insufficient. Therefore, efforts to find a better model always led to rapid and sharp changes.

1.5. Proplem Stament and Aim of Study

Most of us spend an average of 8-12 hours a day sitting down at offices. It may not as harmful as sitting, as told to stand but on the other hand when we are used to sitting for a long time, our body cannot fully cope with the negative effects of sitting, and after a while we start to experience health problems. All day long, especially for those called desk bounded, it is almost too difficult to sit in the right position. The reasons for this vary. For this reason, sitting in a working chair that is in harmony with our body is has a great importance.

Nowadays, office furniture is made according to the predetermined and standardized dimensions. How these measures are determined, whether they are appropriate and their ergonomic suitability are the point of discussion. Apart from the sizes used in the design of office furniture, the material used creates question marks in terms of the structure of the material and compliance with the conditions. Some types of standard chairs are shown in the figure 1.5. The chairs in figure seems ergonomic, but is made with respect to standard sizes. As seen in Figure 1.5, there are standard office chairs. Despite of marketed ergonomically they made according to standard dimensions.

Figure 1.5. Some types of standart office chairs

A healthy working chair should be suitable for the way we work. It should support the sitting position which requires the chair to be adjusted to different working positions. It should also support our skeletal structure in all working positions.

When selecting the work chair, the height of the seat, the lumbar support, the back stiffness, the sitting depth, the neck support or the back height and wheter the armrests are adjustable or not, should be taken into consideration. Office workers spend most of their time in front of the computer screen. Over time, slowly the posture is beginning to deteriorate. The shoulders and neck are moving towards the screen. The upper body starts to bend for a comfortable position. All of this cause our muscles to become shorter and tight, while others are stretched and weakened. That is why many of us are beginning to experience dense lumbar and neck pain as the day ends. Stress starts to increase in the occupants who spend the whole day almost on the seat. As the stress in the body increases, it also becomes difficult to stand up and move. Therefore, it is necessary fulfill the needs of our body in order to work efficiently.

When all this examined, office ergonomics or ergonomic office tools have become signifacently important. Office ergonomics are related to the ergonomic arrangement of the work units. Office ergonomics prevents fatigue and muscle stress; eliminates unnecessary movements; increases comfort.

Ergonomic designs are very important for human life since it directly in a relationship with the health which is one of the most important point of quality life. Our working offices, which we spend most of our time, have a great impact on our health. It is particularly important on our musculoskeletal system.

Therefore, it is appropriate to say that the importance of office ergonomic designs has increased a lot because of the aforementioned issues. With the help of computer aided and digital human modeling methods, more efficient studies have been started.

The aim of the study is to examine the existing office chairs ergonomically and also to see the risk points for new designs. In the study, 3 different standard sized seats have been used. These seats are normally marketed as ergonomic products. In this study, it was found that there are risks at some points. In this study, Kinect technology and DHM software (digital human modeling) were used. The JACK software has been used as DHM. This study showed that the most of the seats on the market are not ergonomic. Advantages and disadvantages of PLM and DHM approaches and methods are discussed. Morever, in this study, the importance of digital human modeling has once again emerged.

PLM approach proved its capabilities as an engineering and business solution approach. DHM has a great impact on the product design which is able to shorten design time and cost. It could be noted that DHM applications is beneficial to analyze human factors in design and product development. Also, DHM applications help engineers to improve more ergonomic product designs, work in safe and examine human factors.

2. LITERATURE REVIEW

2.1. Traditional Prdocut Design and Workplace Evaluation

Traditinonally, although industrial systems, product designs and workplace designs are switched to automatic systems, human hand skills and body motions play a major role. However, The use of the body may cause some physical health problems. These problems inevitably create negative effects which are decrease in performance, Work-related Musculoskeletal Disorders(WMSD). WMSDs describe disorders and diseases of this musculoskeletal system which are suspected to have been caused and exacerbated by a wide extent of work-related risk factors such as abominable work conditions, disorganized working process, shift work and long work hours, excessive force and sustained postures, etc. (Bilodeau et al.1997). It possible to enlarge the examples by stating those, muscle injuries, tendon injuries, nerve injuries, soft tissue disorders etc.

WMSDs occur on different points of the human body, which are mostly caused by non-ergonomic job descriptions or workplaces. The exposure of the muscles, tendons, joints, ligaments, bones to opposite movements and stresses increases the risk of WMSDs. These physiological disturbances are transformed into psychological disorders of the employees over time. There is no doubt that the error rates of related work will increase, the quality of the products will be reduced and even the company's profitability levels will change downward. Companies that have a high opinion of both employees and quality have had to do some work to reduce such kind of problems and to develop systems/products/workstations.

Earlier, the problems were tried to be solved with 2-D models. Significant and important results have been obtained. Similarly, we can see, The first human model that was developed and reported by Boeing on the aircraft cockpit section in the 1960s was the Boeman Model. This model had 23 joints in the first design phase. Designed for anthropometric measurements (shown the figure 1.2.).

The old methods were generally done by 2D studies, but the current studies have been evolved to 3D thanks to development in technology. Currently it is supported by simulation. In the ergonomic area, new modern and rational approaches have begun to take shape.

These approaches have been designed to make people safer, healthier and more productive. The development of these approaches has increased rapidly in the defense and weapon industry. When the studies were examined, many companies worked with the models to improve the productivty and working standards of human. These models are developed and created a transition path between the virtual-real world. They have tried to minimize unhealthy conditions and equipment between the virtual-real world. With the help of the simulations and modeling, the relationship between the real world and the virtual world has been made more realistic.

2.2. Human Modeling Tools

In the past, digital human modeling software has been developed for many sectors of our day. As the successes of these programs emerged, it was seen how important they were. This software has become a big trend, especially with the very well established virtual-real world bridge. Some of the most commonly used programs are described below (Blanchonette, 2010, p.4).

2.2.1. MannequinPro

MannequinPro is a computer aided human modeling application that has been used since the late 1900s. MannequinPro has a huge database of US military and NASA data. The database consists of approximately 11 anthropometric survey data. Male and female modeling can be created with this tool. When we look at the data set is a program that can be done nicely. Helicopter cockpit designs were made with this program (Blanchonette, 2010, p.4).

2.2.2. Technomatix Jack

Classic Jack is the stand alone offering from Siemens PLM Software for Human Factors and Ergonomic Analysis. Classic Jack has several add-on modules which will be covered in this paragraph and have separate training that is available. The first, 3D Body Scan can be used to create humans using existing body scans (such as the SAE CAESAR Scans). The second module, the Occupant Packaging Toolkit (OPT) can be used to maximize vehicle design for the occupant or user. The third is the Task Analysis Toolkit (TAT), which is used in the production group to design better workstation and higher the security of workers. Finally, the MoCap module, which adds the ability to connect to a wide variety of virtual reality hardware for immersive studies (Siemens Plm Software,2014).

In addition to dimensioning human models appropriately for employees, JACK helps us to model many factors such as injury risk situations, user comfort, accessibility, visibility, stress limits and other human parameters.

The JACK software has been used in this study as mentioned earlier. Integration option with Kinect technology software was the biggest reason for choosing the JACK software.

Figure 2.1. Simulation from Jack software, technomatix (Yolcu, 2014)

2.2.3. Ramsis

RAMSIS is a digital human modeling tool that has been started to use in the late 1980s, providing 3D and CAD support for the ergonomic design of automobiles and aircraft. RAMSIS is a CAD model specially developed for the ergonomic analysis of the aircraft, industrial vehicles, automotive (“RAMSIS” , 2019).

2.2.4. Safework

Safework is widely used in automotive, manufacturing and defense industries. It is possible to encounter Safework in many global big companies. For example, in General Dynamics, Daimler Chrysler and Boeing we can see this tool in digital human modeling studies. In addition, some states have used this program. Canada uses this tool in Defense Research and Development. Safework enables us to make ergonomic digital human modeling with human activity analysis, vision analysis, postural analysis andvirtual reality modules (Blanchonette, 2010, p.4).

These tools contain models that are quite close to the human skeletal structure. These models emphasize stress points of human physiological movements. It is aimed to make ergonomic designs on these points. Working areas can be designed by using a number of Computer Aided Design(CAD) modeling tools. The design of standard objects such as office furniture and equipment could be given as an example to it. In addition, some CAD software workspace packages are available and in use.

2.3. Digital Human Modeling and Workplace Designs Case Studies

Tellus One example where human modeling has been applied in a military context is the RAH-66 Comanche helicopter redesign (Kozycki & Gordon, 2002).

The Comanche is a two crew attack helicopter developed as a replacement for the AH-1 Cobra and OH-58 Kiowa Scout (the project was cancelled in 2004). Originally, this helicopter was required to accommodate anthropometrically the central 90% of the US Army male population. Following a policy change in 1993 that allowed females to fly combat aircraft, the helicopter was then required to accommodate the central 90% of both male and female US Army personnel. In addition, new life support equipment was also going to be fitted, which would affect the percentage of people accommodated. Digital human modeling was performed using the jack to increase the usefulness of the two prototypes and to ensure compliance with the overall body size. In this way, some arrangements have been made to make it suitable for people who will use aircrafts (Blanchonette, 2010, p.4).

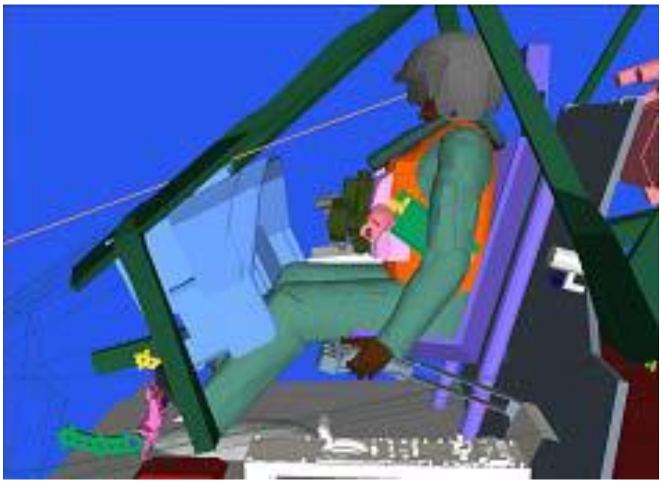

Figure 2.2. Redesign Comanche helicopter (Blanchonette, 2010, p.4)

The mannequin was designed according to the anthropometric limits. In addition, the equipment was virtualized for crews and pilots and virtualized on the models. All equipment such as helmets, boots and lifesaver were considered. After designing the cad model of the helicopter, the mannequin was virtualized and placed in the cockpit section. Various criteria for each pilot, including access to the Comanche, controls and controls, have been set.

The helicopter prototype developed has been made useful in female pilots. While doing this, the databases of both CAD and DHM tools have been used and new data has been created (Blanchonette, 2010, p.4).

Products or goods that service to the public can not be designed according to the person. Standardized human sizes are mostly used and the tools and machines are designed with respect to it. But even with the digital human modeling, the air defense industry has made quite important simulations; and very good results have been obtained. Thanks to the improvements it could be said that 3D and simulation supported software is getting really significant results.

The utilization of DHM for PLM is evaluated by the integration of UGS Tecnomatix Jack, one specific piece of DHM software by UGS, with Dassault Systemes' CATIA V5 PLM software in development of a sample Formula 1 race car. The complete CAD model is designed by using CATIA V5 software (Demirel & Duffy, 2009).

In this study, CAT 5 and Formula 1 racing vehicle parts are designed in a limited way (sub-modeling). It is then integrated on the Jack program by merging these parts. In this way, non-ergonomic conditions are observed in each part according to the sitting position Redesigned cockpit section and seating position with sub-models. Seated positions were modeled in three dimensions to provide a more ergonomic interior. When comfort analysis is performed with the Occupant Packaging Toolkit module, which belongs to the Jack program, the results are among the optimum values (see figure 2.3). Some features of the cockpit were changed and the CAD model tried to make the human comfort ergonomic (Demirel & Duffy, 2009).

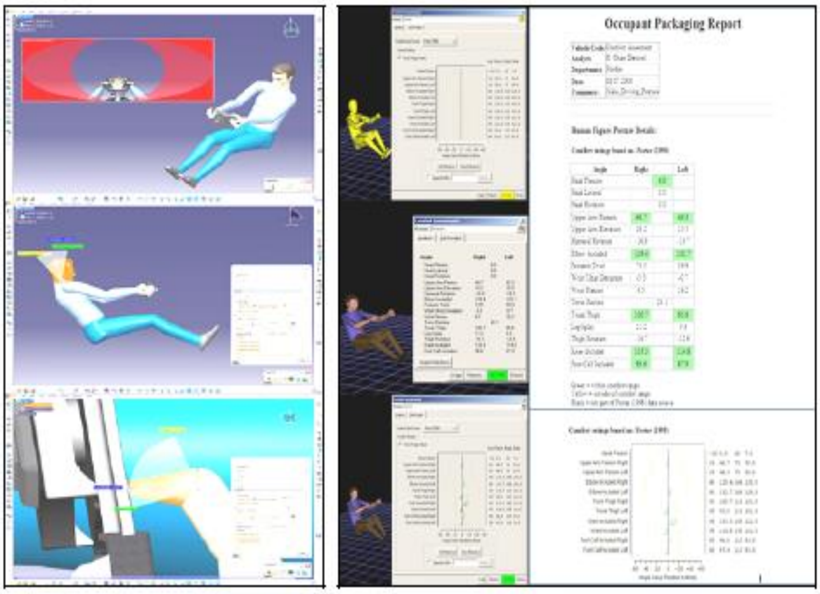

Figure 2.3. DHM virtual design and driver comfort analysis ranges (Demirel & Duffy, 2009)

As its seen in previous studies, digital human modeling contributes for ergonomic design in many sectors and areas. The biggest share is the simulation support of the software and the area used could be states as quite wide. One example is the study of motor sports. One of the most important points in Formula 1 cars is that the cockpit must be very small and ergonomic. Drivers have to stay in these vehicles for more than an hour. Since the cockpit of the cars is small, drivers should not be physically and mentally under pressure. By the help of the mentioned tools the design gained more ergonomic cockpit.

Another example that human modeling has been applied in Healthcare Industry how a DHM tool is modified and utilised to evaluate a bathing system design (Hanson et al., 2009). Most of the tools are used in the fields of automotive engineering, aerospace engineering or industrial engineering. They are applied in the design, modification, visualisation and analysis of human workplace. We also see a study in the health care industry.

DHM tool designed bathroom tub with Delmia V5 Human. bath positions were examined. Virtual mannequin models created. Age criteria were also taken into consideration when creating these models. The anthropometry of the mannequins was changed. Age appropriate views of mannequins were applied.

A number of photos, taken in side-view showing caretakers bathing, were used in order to roughly identify chosen bathing postures.

A stick figure was drawn on the picture to represent the human skeleton and joint angles were measured. The figure 2.4 illustrates different bathing postures (Hanson et al., 2009).

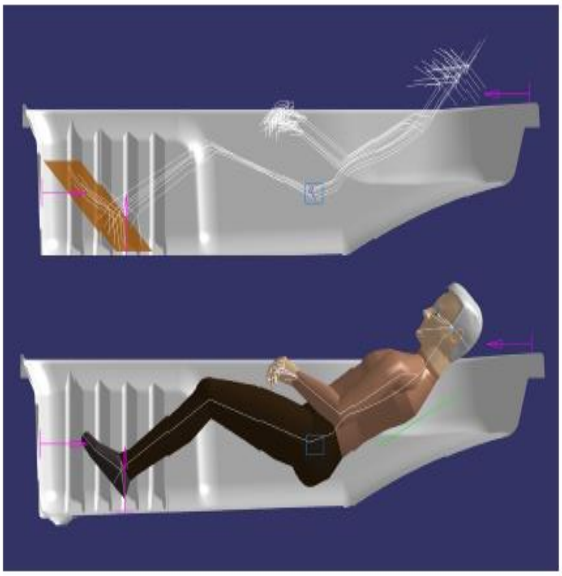

Figure 2.4. Bathing postures (Hanson et al., 2009)

With the DHM approach and CAD supported design work, a new ergonomic bathtub design has been made and the company's product portfolio has also improved.

Another example of human modeling is related to the problems experienced by personnel working with ultrasound devices. Digital Human Modeling was used to solve the problems.

Sonographers are exposed to a variety of ergonomics-related risk factors when they perform specific tasks, dealing with the transportation of equipment, the positioning of patients and equipment and the daily use of Ultrasound (US) systems (Mazzola et al., 2017).

As stated before, the issue of ultrasound systems Ergonomics is treated in many standards and guidance documents from regulatory organizations, Healthcare Institutions and Sonographers Associations. Work-related musculoskeletal disorders are widely common among sonographers (Mazzola et al., 2017). Sonographers are exposed to a lot of work-related musculoskeletal disorders (WRMSD) while examining the patient during the examination.(see the figure 2.5)

At this point, the status of sonographers at 2 points has become very important in terms of ergonomics. As shown in Figure 2.5

1. Status and movements in business area
2. The comfort of used the equipment

Figure 2.5. Status of a professional sonographer. On the left: The working status of a professional sonographer. On the right: the position of the shoulder and the standing position without support (Mazzola et al., 2017)

The ultrasound (US) system should not restrict movement maneuvers for sonographers. It should not cause work-related musculoskeletal disorders while making this restriction flexible. For ultrasound (US) system sonographers, the probes they use must be ergonomic. The probes they use when examining sonographers should not force the muscles of the wrist and wrist. It should not damage the musculoskeletal system. Otherwise, occupational diseases will occur.

In the figure 2.6 , 3 types of probes were selected and the most suitable method was investigated by DHM method. These models are CAD supported and carefully drawn. By working on these models, the skeletal-muscular system tried to minimize stresses.

The opinion that the palmar grip creates less stress on the hands for sonography experts has been confirmed in this study. In addition, the palmar handle, the hand is more suitable for the biomechanical structure of the hand provides more advantages seems to be verified.

Figure 2.6. Types of grips. From left to right: Longitudinal Pincher Grip, Transversal Pincher Grip and Palmar Grip (single fitting) (Mazzola et al., 2017)

It was seen that DHM played an important role in an effective ergonomic design process. More work should be done in the field of DHM for more serious evidence and results.

Cummins Inc., headquartered in Columbus, Indiana, is a corporation of complementary business units that design, manufacture, distribute and service engines and related technologies, including fuel systems, controls, air handling, filtration, emission solutions and electrical power generation systems (Demirel & Duffy, 2009).

The company changes its engine designs in every 2 years. There are some differences in assembly during these designs. Approximately 600 staff should be trained to inform about these differences which causes serious loss of time. To minimize this, the company saved time using simulations of DHM vehicles (a PLM-based JACK software). These programs also allow for a clearer view of the errors that may occur during installation. The company has achieved productive results with product programs. Integration with PLM has a high potential for product development. With the PLM tool it is possible to see all of the design process and keeping the track of challenges

3. MATERIALS AND METHODS

In this study, three seats which are thought to be ergonomic and frequently used in offices have been examined. Armrest, backrest, seat, height, tilt angle, integrated motion maneuver and rotation maneuver have been tested. DHM software (JACK) and Kinect were integrated and co-used in the study. Stress points and pain points in human waist have been tested by Lower Back Analysis. The ergonomics of the seats were tested with this analysis. In particular, L4 / L5 analysis have been performed. BIFMA Guideline and NIOSH limits were used for references points. NIOSH Limits were embedded in DHM Software (JACK).

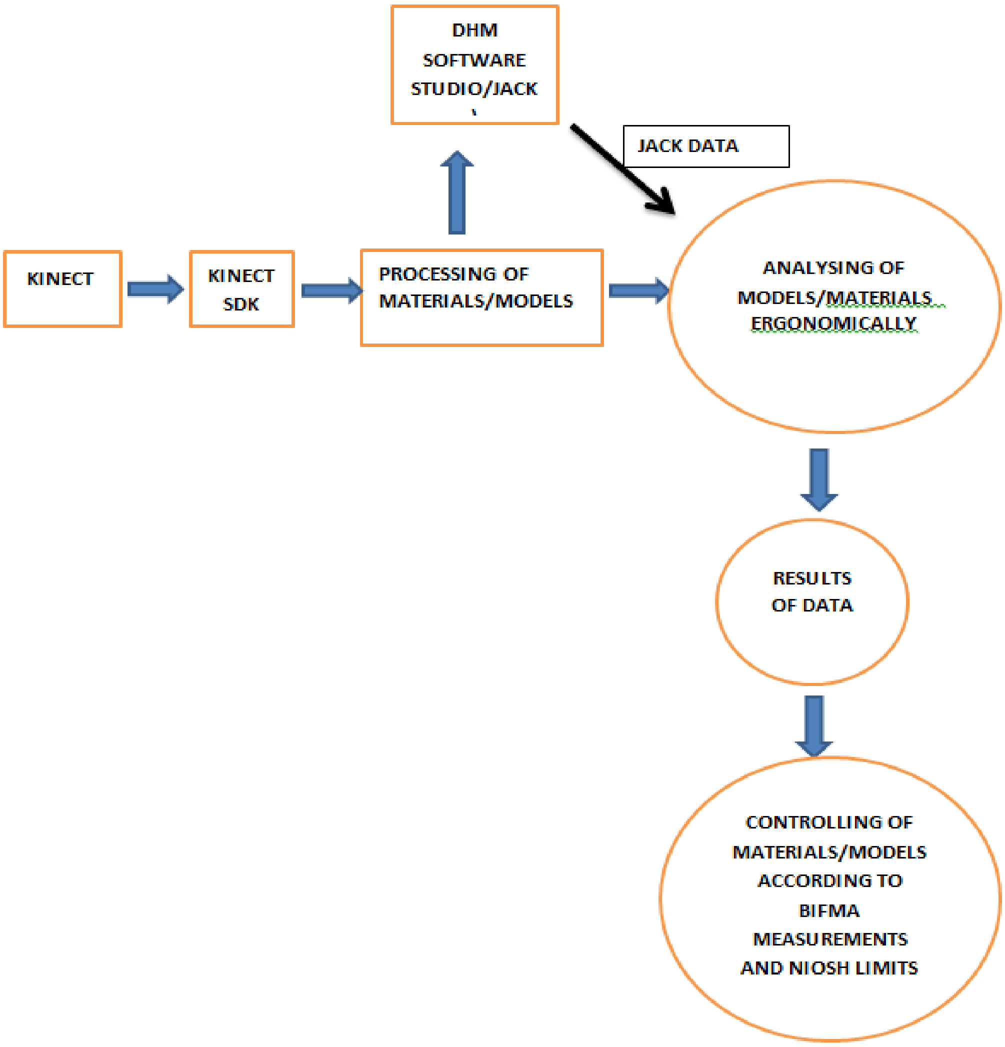

Fig 3.1. Testing Architecture

The models and materials has been choosen to detect whether they are ergonomic or not. After Kinect detect the models, the data has been checked by DHM Software (JACK). The examination have just started with the Lower Back Analysis Modul on JACK. The loads/stress points on L4/L5 have been checked at the same time. The results have been compered according to BIFMA Measurements and NIOSH Limits. Testing Architecture is given in Fig. 3.1.

3.1. Materials, Hardwares and Softwares

Materials, softwares and hardware have been utilized in this study. Office chairs were used as testing material, Technomatix Jack program was used as software and Kinect Technology software has been used as hardware.

3.1.1. Microsoft Kinect

Microsoft Kinect could be defined as a sensor that can detect human movements thanks to the cameras developed by Microsoft. The most prominent feature of Kinect is its perception of human movements. Kinect has 3 sensors RGB, sound and depth sensors. These sensors recognize the user's movements and face. Thanks to this technology there is no need to wear any further accessories, Kinect recognizes the user with its own sensors. Kinect is a widely used hardware and Xbox, health sector, industrial design and applications, information technology sector, Media and Advertising Sector and Education are some examples to it.

Figure 3.2. Kinect (Bozkurt, 2015)

Kinect specifications can be listed as follows;

Features of RGB camera:

1) 1.3 megapixel color camera
2) Micron MT9M001
3) Equipped with IR (Infrared) pass filter
4) 32-bit color and 30 frame / sec
5) has a picture resolution of 640 x 480 pixels.

Sensor:

1) Color and depth detection lenses
2) Audio microphone layout
3) Sensor to adjust the tilt motor

Field of view:

1) Horizontal field of view: 57 degree
2) Vertical field of view: 43 degrees
3) Physical Tilt area: 27 degree
4) Depth sensor area: 1.2m - 3.5m

Data Flow:

1) 320x240 16-bit depth - 30 frames / sec
2) 640x480 32-bit color - 30 frames / sec
3) 16-bit audio - 16 kHz

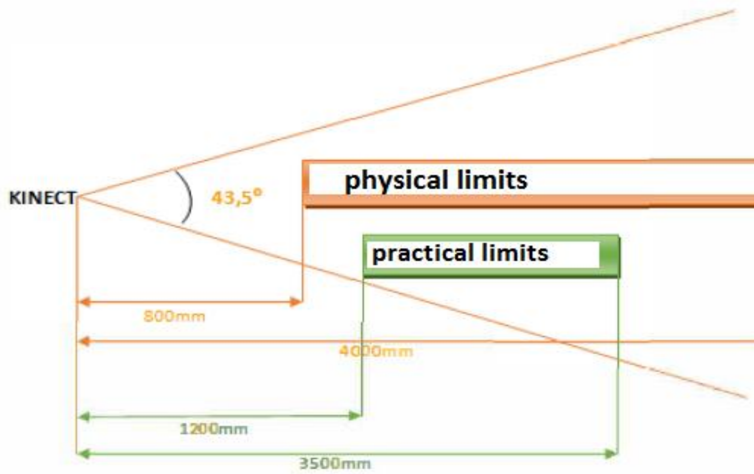

Figure 3.3. Detection limits of the Kinect sensor (Yolcu, 2014)

In Figure 3.3, Kinect detection ranges are given. Figure 3.3 shows the effective range of the device.

The most important feature of the Kinect hardware could be stated as its' sensors which can calculate the distance of each point in an image by the camera. For this calculation, Kinect primarily sends infrared rays to the user and then calculates the time it takes for the rays to return back to the camera. In this way, the depth information of objects can be calculated. The depth information can provide great convenience as shown in the figure 3.4 where the RGB photo from Kinect shows the depth image of the same media.

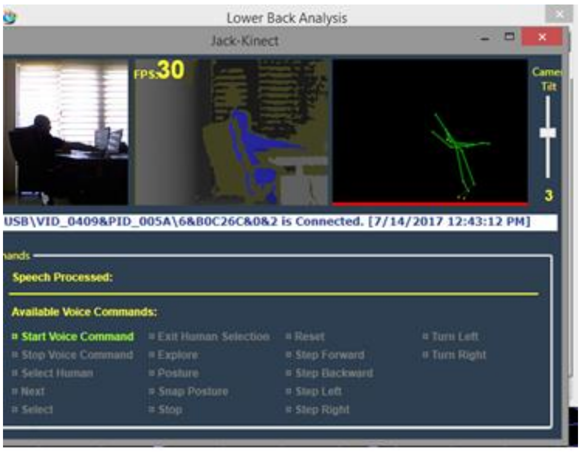

Figure 3.4. RGB photo and depth image

Although Kinect was originally developed for the Xbox game sensor, Kinect SDK is also used in Windows applications. Kinect needs to be connected to a PC via USB (Universal Serial Bus) and powered by an external source to get 5V power to work with the computer. The Kinect camera acts as a camera in applications and transmits the image as pictures. This makes the image much easier to access (Yolcu, 2014).

One of the biggest features of Kinect technology is the skeleton detection and monitoring system. With the infrared camera installed to Kinect hardware, the moving joints of human body can be detected and monitored. When human anatomy is examined, 20 different motion points are seen as its shown in Figure 3.5.

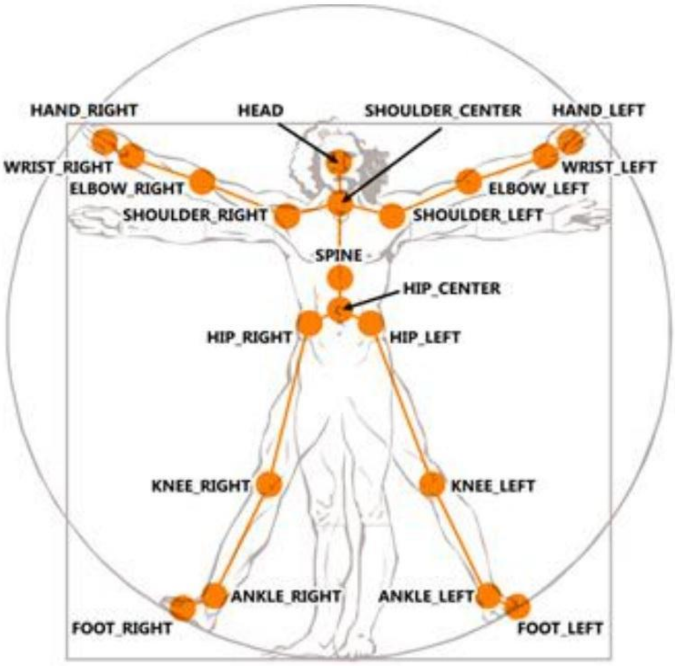

Figure 3.5. Joint regions of human detected by Kinect (Süzen, 2012)

Kinect has the ability to detect 20 different points in the human as mentioned before. Kinect cameras are capable of actively detect and monitor 20 different regions of 2 different people at the same time. 20 different regions detected by Kinect are given in Table 3.1 as follows;

Table 3.1. Regions detected by Kinect (Sidik et al., 2011)

Regions of Human	
Head	Neck
Left Shoulder	Right knee
Left Foot	Right Shoulder
Left ankle	Right ankle
Left Elbow	Right wrist
LeftWrist	Right foot
Left hip	Right hand
Left hand	Right hip
Left knee	Mid Hip
Breast	Right Elbow

3.1.2. Siemens Technomatix Jack (Modeling Software)

Technomatix Jack is a comprehensive digital modeling solution that controls product engineering, production engineering and production units. Technomatix Jack helps the user to build more efficient, lower-costed and higher-quality systems by looking at the effects of the cycle in place of a product's lifecycle. Technomatix solutions examine the relationships between product and production processes, ensuring that the entire process reaches the optimum values. These values may originating from human or environment.

3.1.2.1. Background

Siemens' JACK digital human modeling is a Product Life Mangement program. Siemens' JACK digital human modeling and ergonomics software product, together with Motion Analysis, have introduced an advanced simulation, modeling and analysis tool which operates in real-time. The JACK Plug-in enables real-time motion capture data from a Motion Analysis system to be viewed in the JACK software. Jack is a complete system for generating 3D environments or virtual worlds and interacting with them in a powerful graphical environment (Siemens Plm Software, 2014).

3.1.2.2. Jack Structure

At the highest point, a scene in Jack is composed of one or more objects that make up the work area and the people who work in it. At the next lowest point, objects and people in the environment are called figures. The figures may be anthropometrically articulated model of any human or object, such as an office environment, vehicle cockpit or a mouse.The figures are represented by a simple polygonal geometry consisting of several flat surfaces, usually triangular faces, defined by joining three or more points each. Jack figures are represented by polygonal shapes, each of which consists of several flat surfaces, each coming to a track with three or more points (Blanchonette, 2010).

Figures can vary depending on the state of the objects. This is sometimes a few dozen polygons per mouse, but sometimes it can consist of hundreds of polygons for an aircraft. Jack consists of joints that connect the segments together for a shape of the lower level joints.The information describing the environment is hidden in a media file that creates the entire scene.Environment (.env) files contain information that identifies the joint angles and locations, as well as figures (people and objects), sections (building blocks of figures), the relative positions of the figures and their geometry scaling, limitations, and additional information. Joints, sections, colors and descriptions are included in the figure (.fig) file. Data describing the segment geometry is contained in a polysurface (.pss) file (Blanchonette, 2010).

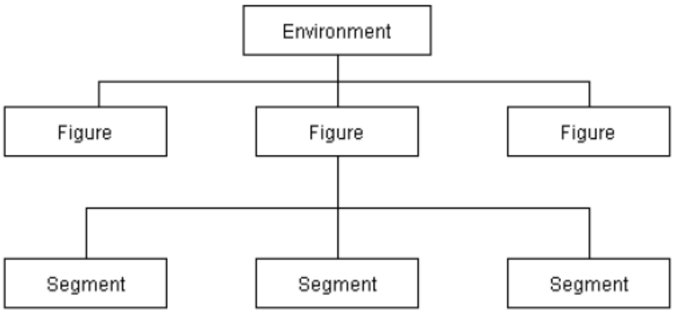

Figure 3.6. The Jack hierarchy (Blanchonette, 2010)

3.1.2.3. Graphical User Interface

The graphical interface of the Jack software basically consists of two parts. First, a control bar shown in Figure 3.7 which consists of several drop-down menus for creating objects and people and conducting workplace analyzes. Just below the line of icons, there is a message field that provides feedback about the current process (for example, indicates the status of importing a file). Mannequin in Jack shown as Figure 3.8.

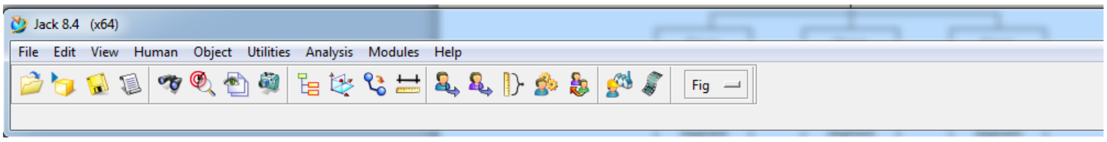

Figure 3.7. The Jack control interface

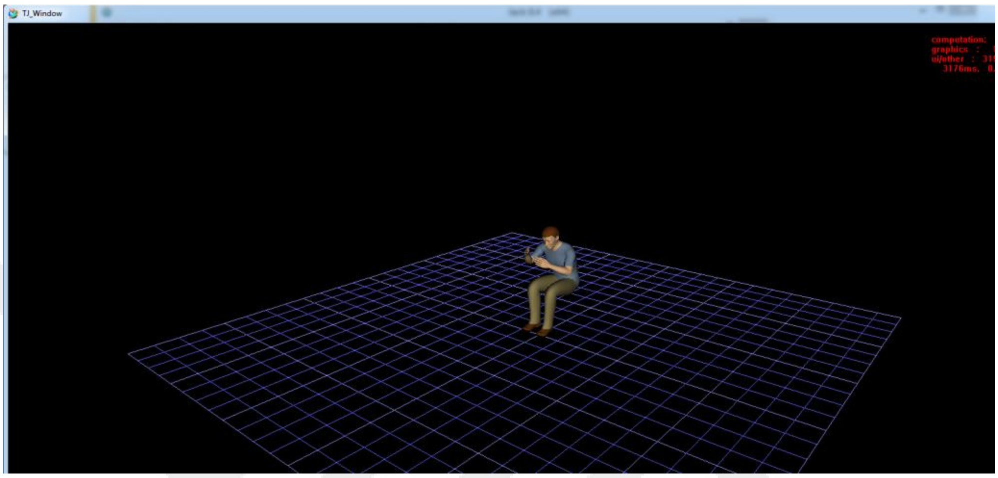

Figure 3.8. The Jack graphics window showing a mannequin

3.1.2.4. Lower Back Analysis (Lumber Spine)

Lower Back Analysis quite beneficial to assess the forces and risky situations on the spine. It is an effective analysis especially for situations during posture and loading which will also be mentioned with details in following chapters.

3.1.2.5. Spinal Column

The spinal column consist of 26 bones: 24 vertebrae and additionally the sacrum and coccyx at the end of the backbone. The Vertebrae can be visualize chain where the elements of chain connetced to each other.

The parts of the vertebrae can be listed as follows:

• 7 cervical vertebrae which make up the neck

• 12 thoracic vertebrae of the chest

• 5 lumbar vertebra or the “lower back” abbreviated as; L1, L2, L3, L4 and L5 which were shown in figure 3.9 and it should be noted that the sections L4/L5 vertebras are the most important for parts regarding the study.

The back can be exposed to many installations while moving in many different directions. This can get stiffer. As our spine looks flat, there are actually 2 curves that cause the back to be ”S“. It is leaning forwards (cervical spine) and backward in the lower back (lumbar spine) and thoracic spine and sacral region. These curves provide the flexibility while keeping the head strong, and provide a benefit that absorbs super shocks. Many problems in the back are related to the loads that the back is exposed to (“ Lumbar Spine (Lower Back) Anatomy and Function”, 2019). Lower Back Analysis helps us to assess the forces and risky situations on the spine.

Between each vertebra is a cushion called an intervertebral disk. On the anterior side of each vertebra is an oval shaped disk called the vertebral body. On the posterior side of each vertebra is the vertebral foramen, which is an opening through which the spinal cord passes. A crucial job of the back is to protect and support the vital spinal cord and spinal nerves (“Lumbar Spine (Lower Back) Anatomy and Function”, 2019).

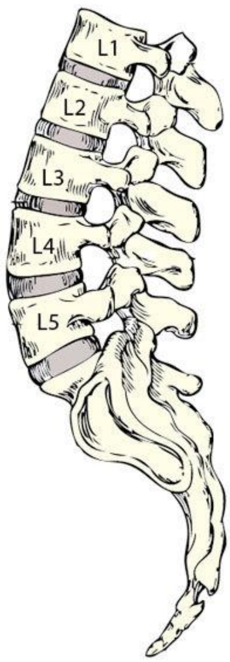

Figure 3.9. The Spinal column (“Lumbar Spine (Lower Back) Anatomy and Function”, 2019)

3.1.2.6. SpinaLower Back Analysis Screen

The Lower Back Analysis tool provides to evaluate force on the spine that affect the lower back of a virtual human model under a posture and loading. The lower back analysis tool screen user interface has shown in figure 3.10

The Lower Back Analysis tool also provides to analyze some of the following points.

a) Examination during a job, whether the worker exceeds the NIOSH limitations or not.

b) The tests regarding of the level of stresses with respect to NIOSH limitation in related areas.

c) The observation of the forces on lateral shear, lower back compression, anterio/posterior shear.

d) Torque measurment of L4/L5 sections.

The Lower Back Analysis tool is used to; minimize the risk of lower back and waist injuries and it also adjusts compliance with NIOSH limitation and provide an ergonomical designs.

With this tool it is aimed to analyze the compression and shear forces and checking NIOSH limitations in related parts which are affecting the sections L4 and L5 vertebra joint and minimize the injuries.

This tool shows the effect of sagittal, lateral and axial spinal reaction moments (torques), upper body weight and hand forces on the L4 / L5 disc. (Siemens Plm Software, 2014).

The main point of this thesis is to use the lower back analysis method to observe the points where the spine system is exposed while doing work on the seats. The waist will be analyzed to prevent injuries. In addition, observations will be discussed ergonomically and particularly, the forces on sections L4 and L5 will be examined.

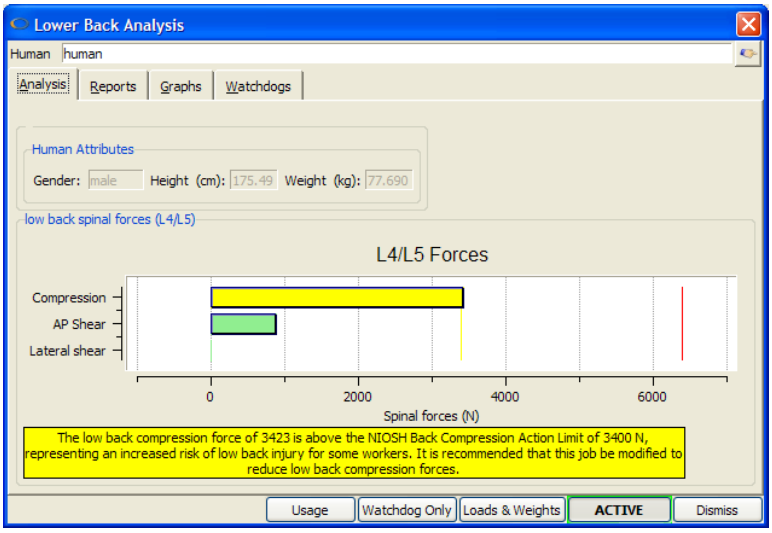

Figure 3.10. Lower back analysis screen (Siemens Plm Software, 2014)

3.1.3. Office Chairs

It is waited for ergonomic office seats to satisfy some standardized sizes for each parts on it according to BIFMA Guideline which are shown in table 3.2 and illustrated in figure 3.11.

As summary, seat height should be between 15.0 and 19.9 inches. Foot height should be adjusted well and If necessary, some underfoot equipment should be provided for more support. Seat depth should be deep enough as specified in guideline and it should not restrict movements. Same as the depth the seat width should also be wide enough for the buttock. Backrest should be appropriate to the back of the person and it should give support to person’s back all the dimensions should be in limitations to provide a feasible ergonomic design.

Chair Range of Motion must be adjusted and played. They should be able to be moved to their tiltable position when necessary. But it should also allow for wider angles. A minimum 10 degree rearward tilt (between 90 degree and 115 degree) is preferable. Some chairs also allow the seat to tilt at the same time. The only guidelines for seat tilt measurement is to ensure the torso-to-thigh angle is not less than 90o, and that the seat angle is between 0-4 degree reward tilt (Openshaw& Taylor, 2006).

It is also important to mention about armrests which provide to reduce the stress on the spine. They should be designed specifically to reduce pressure on the arms and in addition they must be 4-way adjustable

Table 3.2 Detailed guideline measurements of BIFMA chair design. All measurements are in inch (Openshaw& Taylor, 2006)

	Letter	Measurement	BIFMA Guideline
Seat Height	A	Popliteal height + Shoe allowance	15.0” – 19.9”
Seat Depth	B	Buttock-popliteal length – Clearance allowance	No deeper than 16,9” (fi xed) 16.9” included (adjustable)
Seat Width	C	Hip breadth, sitting + Clothing allowance	No less than 18”
Backrest height	D	None	At least 12.2”
Backrest width	E	Waist breadth	14.2”
Backrest Lumbar	F	None	Most prominent point 5.9” – 9.8” from seat pan, in and out 1
Armrest Height	G	Elbow rest height	6.9” – 10.8” 7.9” – 9.8”
Armrest Length	H	None	None
Distance between Armrests	I	Hip breadth, sitting + Clothing allowance	18” (fixed) 18” included (adjustable)

Figure 3.11. Measurements used for ergonomic chairs, for visualization (Openshaw& Taylor, 2006)

3.2. Antropometric Measurements And Current Office Chairs

Office chairs have become undoubtly important materials for modern working people because of the long working hours. During this long hours on furniture, the backbone system exposed to number of loads. These loads need to be minimized in order to satisfy more ergonomic spaces. Many seats in everyday life are could not stated as ergonomic but on the other hand it is possible to say that ergonomic seats have been done in recent years. In this study, some software and hardware works have been ran co-operatly. The samples which are standart chairs were shown in the figure 1.5. previously and significant results have been obtained.

3.2.1. Anthropometric Measurements

Anthropometry is the study of the measurement of the human body in terms of the dimensions of bone, muscle, and adipose (fat) tissue (Westat Incorporation, 1988). Anthropometric dimensions for each population are different and shown as percentiles. It is common values to designs for the 95th percentile (95th%) male to 5th percentile (5th%) female (Westat Incorporation, 1988).

A 5% female value in a population can be the smallest value for any size. On the contrary, any value of 95% male can be the largest. Approximately 90% of the population is between 5% and 95%. To design a larger proportion of the population, a 1% female to 99% interval can be used as shown in figure 3.12

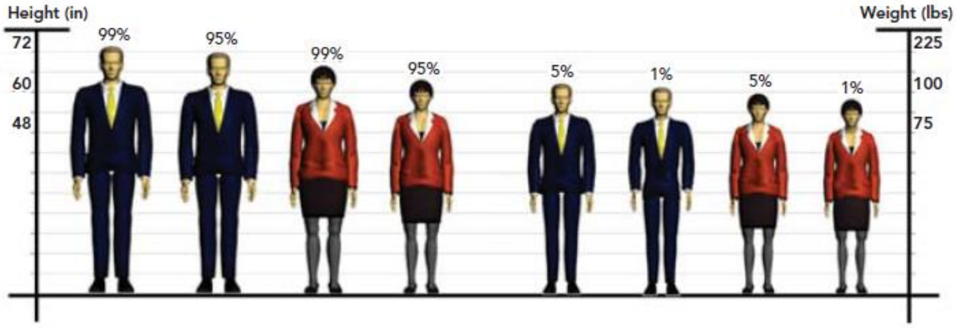

Figure 3.12. Sizes of percentile human (Openshaw& Taylor, 2006)

3.2.2. Workplace Postures

There are frequently repeated positions in the office environment. These positions are important for the musculoskeletal system. During these positions, our back bone system may be subjected to lots of loads. The general posture and position types could be listes as follows;

• Standing
• Sitting
• Reaching
• Moving

3.2.2.1. Standing

It may be necessary to stand for some work and ergonomic furniture should be designed for this type of works. The distances between the eye and the work should be optimal for long continued jobs. Otherwise, some difficulties in the neck may begin to appear. Variable work stations have shown in figure 3.13.

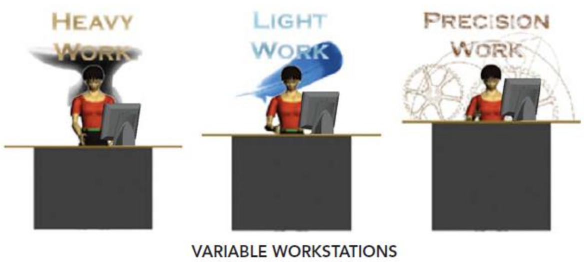

Figure 3.13. Variable workstations (Openshaw& Taylor, 2006)

3.2.2.2. Sitting

The sitting position is one of the most space-consuming posture in the musculoskeletal system. This position is the most common activity in in-door office environments. Therefore, indoor office environment furniture, especially the seats need to be very ergonomic. An overloading situation can disrupt the entire skeletal system. Common sitting anthropometric measurements are shown in figure 3.14 and Table 3.3.

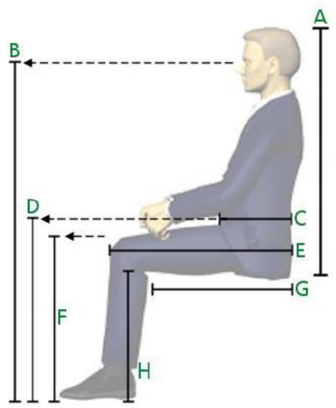

Figure 3.14 Sitting anthropometric measurements (Openshaw& Taylor, 2006)

Table 3.3 The ergonomic measures of fit for men and women between 5% and 95% are shown. All measurements are in inch (Openshaw& Taylor, 2006).

Measurement	Letter	Female 5th – 95th%	Male 5th – 95th%	Overall Range 5th – 95th%
Sitting Height	A	31.3” – 35.8”	33.6” – 38.3”	31.3” – 38.3”
Sitting Eye Height	B	42.6” – 48.8”	46.3” – 52.6”	42.6” – 52.6”
Waist Depth	C	7.3” – 10.7”	7.8” – 11.4”	7.3” – 11.4”
Thigh Clearance	D	21.0” – 24.5”	23.0” – 26.8”	21.0” – 26.8”
Buttock-to-Knee	E	21.3” – 25.2”	22.4” – 26.3”	21.3” – 26.3”
Knee Height	F	19.8” – 23.2”	21.4” – 25.0”	19.8” – 28.0”
Seat Length/Depth	G	16.9” – 20.4”	17.7” – 21.1”	16.9” – 21.1”
Popliteal Height	H	15.0” – 18.1”	16.7” – 19.9”	15.0” – 19.9”
Seat Width	Not shown	14.5” – 18.0”	13.9” – 17.2”	13.9” – 18.0”

3.2.2.3. Reaching

When sitting or doing a job, reaching is a frequently made movement. During the reaching position, the body may still have exposed to undesirable loads. So in order to minimize the risk of injuries the person who move should pay attention to not expose undesirable loads and additioanlly workstations should also be suitable to facilitate movements.

3.2.2.4. Moving

Moving is one of the most important topic to discuss in this study since it runs a huge composition of elements in musculoskeletal system. People must act to achieve something basically and these movements should not force the skeletal system. In fact, motionlessness should also be mentioned under this title since some of the work is very static and can remain steady. These inactivity should be taken into account and people should prevent some kind of disorders by moving frequently. It is beneficial to activate the blood flow, otherwise, it is possible to have some blood pressure related diseases.

3.3. Testing and Analyzing

3 different chairs have been used in this study. The study has been made in an office environment of a firm which operates in private sector. The chairs have been used in study has been showed in figüre 3.15. and they tested with DHM software and analyzed to answer whether they are ergonomic or not. Finally, according to BIFMA measurement standards they are subjected to comparison.

Fig 3.15. Chairs used in the study from left to right ; Ch1, Ch2 and Ch3

At first, the first sample (Ch1) was tested by the help of JACK program which has shown in figure 3.16

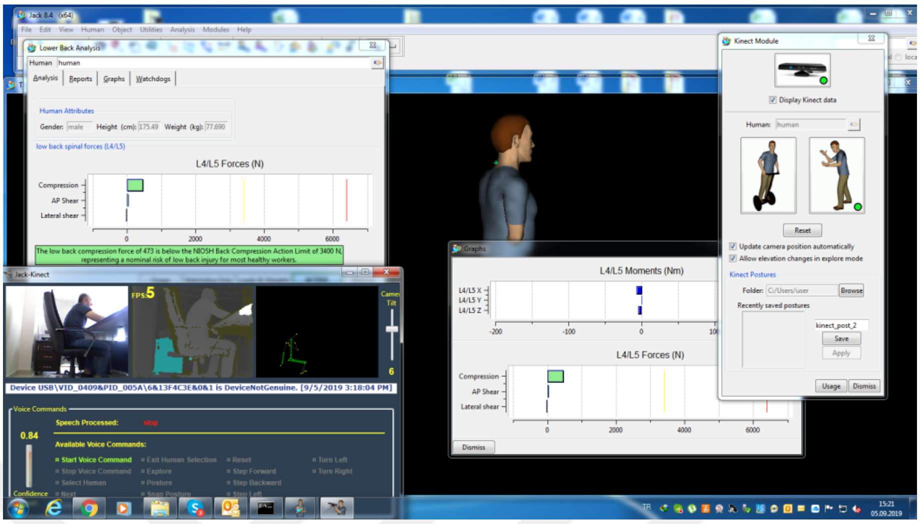

Fig 3.16 . Analyzing results of Ch1 on DHM Software (JACK)

When the results of the analysis were obtained and examined, uncomfortableness have been detected in L4 and L5 sections. Some stress points and overloading have occurred which can cause injuries to employees over time.

After the analysis of first sample, the second sample (Ch2) was tested in the JACK program which shown in figure 3.17.

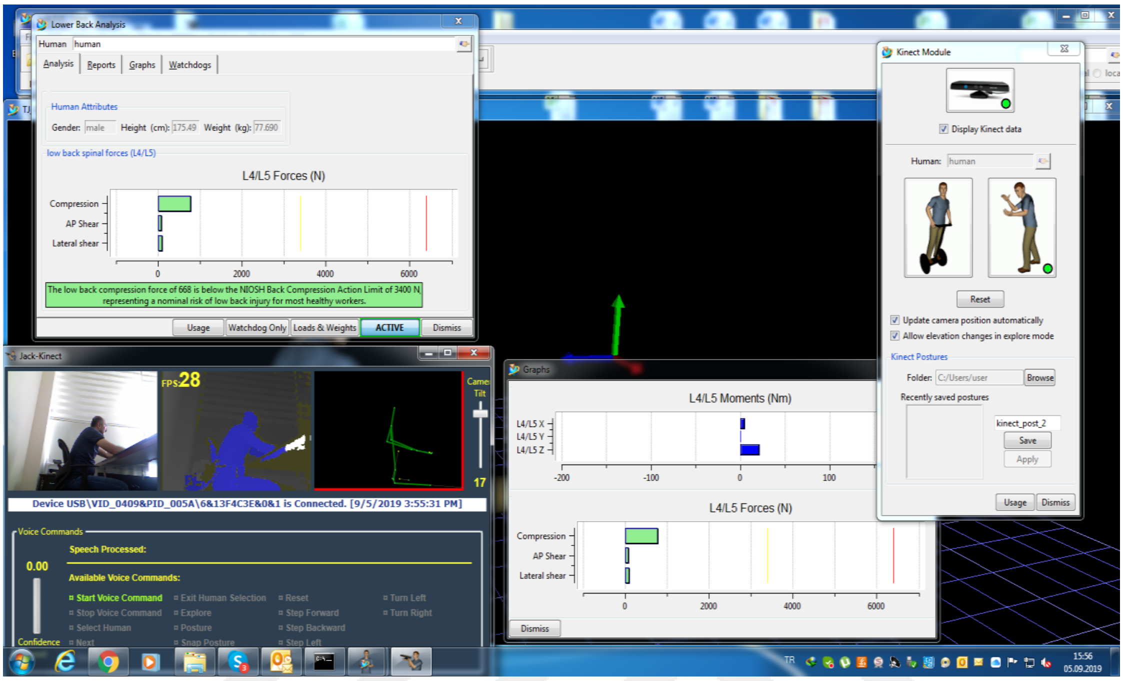

Fig 3.17 . Analyzing results of Ch2 on DHM Software (JACK)

When the results of the analysis were obtained and examined for Ch2, uncomfortableness were observed in sections L4 and L5 same as sample 1 but the values of these points were even worse than Ch1 results and Similar to Ch1, overloads have been appeared on Ch2 as well.

After the analysis of second sample, the last sample (Ch3) was tested with the JACK program which shown in figure 3.18

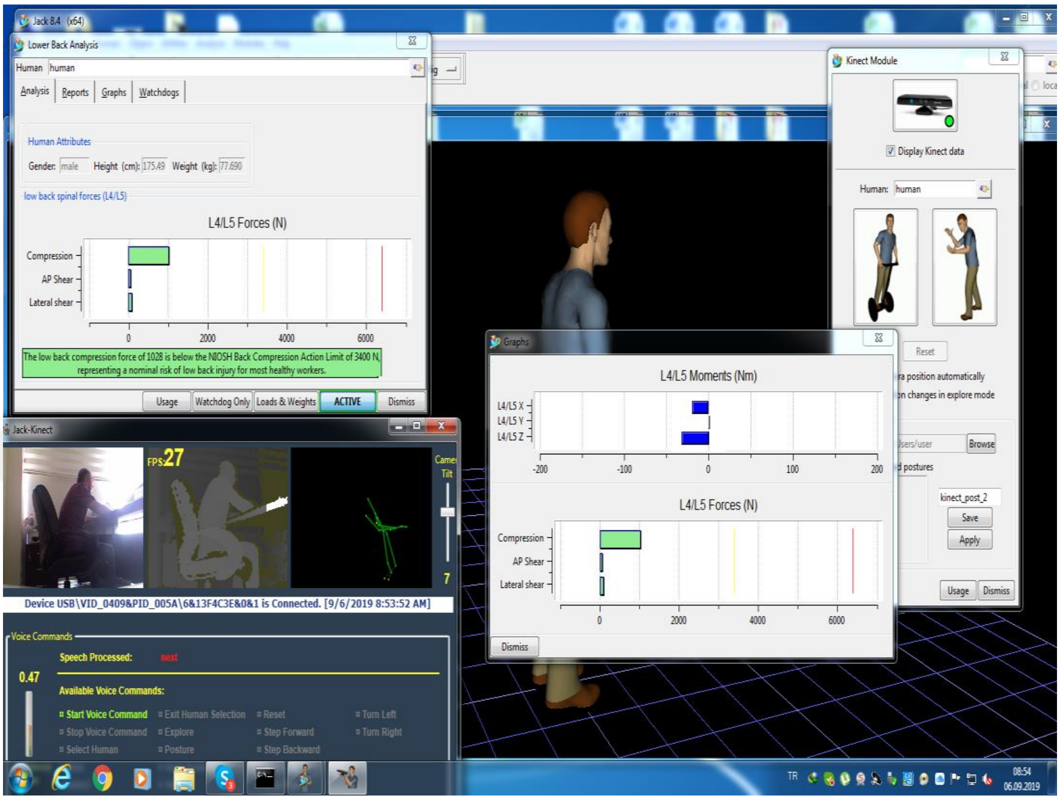

Fig 3.18 . Analyzing results of Ch3 on DHM Software (JACK)

When the results of the analysis were obtained and examined for Ch3, uncomfortableness were observed in sections L4 and L5 same as previos two samples. The results belongs to last sample (Ch3) could be stated as the weakest one. Even though samples were generally out of standards and weak with their performances it is possible to say that the first sample (Ch1) had better indicators.

The effective integration of Kinect with DHM software have demonstrated quite efficient analysis results. L4 and L5 stress values are out of range with respect to ergonomical standards. Additionally, overloads occurred on the waist. If these overloads and stresses could not be fixed and redesigned, lumbar discomfort could began to occur. At this point, the importance of digital human modeling program emerges. However, these overloads can be reduced by lower back analysis method with the help of DHM software.

4. RESULTS AND DISCUSSIONS

In this thesis, Kinect technology is integrated into Digital Human Modeling programs. Lower back analysis was performed with three different types of chairs. The results have showed that these chairs submittet to the tests were not ergonomic. It has been seen that this method can give direction to ergonomic designs and once more it came out that making an ergonomic design is a really difficult process.

During the hours spent in offices, it was seen that the human body was subjected to some stresses. These difficulties have caused various occupational diseases in humans. These diseases have been increasing in recent times since the changing life styles as we mentioned in the beginning of this study. In addition to occupational diseases, many injuries have started to occur. Considering all of this, the importance of ergonomic design is even much more crucial then before and the need for ergonomy shows an inrease. Ergonomic designs often require cost and time. A number of digital human modeling systems have begun to be developed to get efficient results from time and cost. These programs gave good results in a very short time. These programs have increased productivity, they reduced the costs, improved the life quality of personnel, by increasing the comfort, and equipment as well. Moreover, modeling systems intertwined with simulations have become vitally important day by day. Everything for the human ergonomics science has once again have showed how important is ergonomy for human being. It is worth to mentioning it again that, in this study, the efficiency of Kinect technology and digital human modeling systems have gave great results for the study.

The models which have been submitted to test have shown in figure 3.15. The samples shown were used as a standard office chairs. These seats ought to be manufactured according to standard values. But in fact, most of them were manufactured without even considering the standard sizes. Thanks to the digital human modeling program (JACK), in figure 3.16. figure 3.17. and figure 3.18. it is possible to observe in how unhealthy situations the office workers are operated respectively.

Table 4.1 Comparing of anthropometric measurements shown.

MEASUREMENTS LETTER	CH1	CH2	CH3	BIFMA GUIDELINE
A	18,50	20,08	17,72	15.0” – 19.9”
B	20,47	19,69	18,90	No deeper than 16.9” (fi xed) 16.9” included (adjustable)
C	20,47	19,69	22,44	No less than 18”
D	28,74	18,50	19,69	At least 12.2”
E	20,08	18,50	20,87	14.2”
F	3,94	4,33	5,91	Most prominent point 5.9” – 9.8” from seat pan, in and out 1
G	8,27	7,48	12,60	6.9” – 10.8” 7.9” – 9.8”
H	12,60	10,24	13,39	None
I	20,47	21,26	20,87	18” (fixed) 18” included (adjustable)
All measurements are in inch				

In additon, When Table 4.1 is examined, it is seen that three chairs are not satisfying the ergonomical conditions. There have been some stresses in the body. Table 4.1 was formed by measuring each chair after precise analysis of the chairs. BIFMA measurements were compared with those chairs which have submitted to test in this study. Lower Back Analysis are also shown in Figure 3.16, Figure 3.17 and Figure 3.18 respectively, and it is also possible to see how the samples fail the test from the figures.

The results of the study show that, the effective integration of Kinect technology with digital human modeling programs has helped the problem holder to obtain very beneficial ergonomic analyzes. With a successive integration which is composed with the correct analysis methods and knowladge it is possible to design quite comfortable workstation, office furniture and a better working enviorenment for human.

5. CONCLUSIONS

In this study, digital human modeling method is explained and experienced in detail which focused on the ergonomical conditions of the sample that we choose previously. This work is supported by the Kinect and JACK (PLM program). It is a must to have the Kinect device to create the model. The work carried out with Kinect technology has brought along with the problems arising from the new Kinect technology. Since the Kinect technology has a low sensing distance, it has seen that the model has some difficulties in some aspects. For example, when the user moves, the arm can move out of the model at the background. This could be counted as a disadvantage for the study. There may be occasional synchronization disorders in the system. To prevent this, many more virtual models should be created and added to the database.

Firstly, the ergonomic status of the existing office chair was examined with the help of Jack Program and Kinect technology. The incidence of work-related musculoskeletal disorders (WRMSD) have been observed and stress points were tried to be eliminated. In addition, the status of employees in many aspects was noted. Analysis obtained was quite successful. In this study, the aesthetic aspects of product development challenges for an ergonomic product have been increased with the up-to-date engineering technique.

The PLM approach proved itself by solving the challenges in engineering and workstations. In addition, DHM practices lead to ergonomics and human factors development in design. DHM has an important role in product design and has been shown to shorten the time and cost in design. In literature search, cockpit designs and Sonographers device design applications, effective integration of DHM and PLM can be an effective solution for product development. Great tools can be designed for prototype and human comfort and safety before production.

Design of complex structures and human factors can be visualized by DHM and PLM integration. Effective integration with DHM and PLM can control the entire product life cycle. As a result, it is quite understandable to say that the success rate can be increased with an environment where the office furniture and work stations can be modeled more effectively. The method can generally be re-considered and the kinematic attributes used may be more decisive.

As a result, the results obtained with the help of the sensor installed to Kinect hardware and the JACK program confirm that DHM modeling can improve products and working enviorenment significantly. The fact that DHM tool technology is a new technology and the number of studies done on it is not too much, it increases the scientific importance of this study. The successes in the military and automotive sectors have once again revealed the importance of this technology. In addition, it aims to guide similar studies because it targets all areas where human factor is present.

6. RECOMMENDATIONS

It is expected to increase the use of kinect technology on a much larger scale thanks to rapidly developing digital human modeling. In the near future, the science of ergonomics is expected to make a remarkable leap.

This thesis show that DHM is an impressive approach which makes the Kinect hardware much more beneficial. The use of the Kinect sensor to capture the optimum ergonomic values for the body and the integration of the computer-specific drawing and engineering approach helped to the study to achieve a simple and effective result. There were of course some problems faced becasue of Kinect! But it was tried to minimize. Optimum values were tried to be achieved by using more angles and samples.

Kinect provides a better view of the segment and attachment sites in the musculoskeletal system with the help of the depth camera and infrared sensors. Additionally, Kinect helps a lot to track movements. There are some disadvantages in the system, but in some way it is possible to achieve the best values by various methods. These disadvantages can be solved with too many samples and different angles. It is also said that if additional equipment is used, better results can be obtained. Although the purpose of the study is for a seat in an office environment, these systems play a very important role in development of technology. This importance is increasing day by day. These types of systems have a lot of advantages and increases the quality of the working enviorenment of the people countinously.

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