Thesis for the Degree of Master of Engineering

A Design of a Work Desk for Persons in a Wheelchair

by

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by

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A Design of a Work Desk for Persons in a Wheelchair

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Abstract

It is very important to identify the problems associated with the working space for disabled employees in administration. However, since the problems of disabled employees are very extensive, this paper will focus only on a selected area, which is spinal cord injury in T10 - L3 and L4-S2 (Low paraplegia and paralysis). The main goal of this work is to propose the parameters for the ideal work desk and adjust the workplace for a persons in a wheelchair . In this work, the comparison of the requirements between the healthy worker and the worker with a disability has been performed. Moreover, specific standards for the dimensions of the wheelchair, wheelchair turning radius, anthropometrics of chairbound people and the parameters of office equipment are presented as well. The data of workers with disabilities is subsequently used for the creation of a visual workplace design in JACK human simulation software and also for

manual drawings of the final design. The proposed work is to improve working conditions of employees with disabilities. In addition, this work will stimulate more interest in the employment of persons with disabilities and help to improve the view of equality in society.

1 Introduction

Illness or disability represent an extraordinary burden, which is a test of endurance and a challenge for handicapped people and also for their family, friends and carers. At the same time it brings a lot of limitations and major changes in lifestyle and levels of stress.

There are around 650 million people with disabilities living in the world right now. 400 million of those people live in Asia and the Pacific, and more than 40% of them live in poverty. This number is increasing every year and it will be receiving increasing attention[(1)]. These people are challenged with a lot of barriers during their life. While some people approach them with a lack of interest and arrogance, other people exaggerate compassion and pity. However, people with disabilities are the same as others and aspire to be well perceived in society.

The majority of them have no problem with participating in daily life, and most are also able to work. However, more than half of those who want to work and can, are not able to find work.

Even though it can be objectively shown that a disabled person is capable of performing to the same standard as an healthy person, employers frequently refuse to employ them for other reasons.

These include the fact that they can not fully meet the needs of the disabled person with regard to the requirements of the working environment, working space and regime required for work activities[(2)].

The idea is design a workspace where people with disabilities will have a better chance to get involved with the work environment. South Korea is currently among the countries which realized how important it is to remove the barriers which are making it difficult for disabled people in their life, and their needs in the workplace. That is the reason, why the state tries to motivate companies to employ disabled persons, by providing incentives, tax breaks or subsidies. But despite efforts of the state or organizations, in most cases, companies prefer to pay the money to the state budget than employ disabled persons and thus do not have to worry about the modification of the workplace. Until now, however, nobody paid too much attention to setting requirements or recommendations on the quality of the work environment of affected employees. However, many of those who really care about the quality of working life for disabled people, do not have much experience with modifying their workplace.

The objective of this work is to identify the problems associated with the adjustment of the working desk for disabled employees in the field of administration.

Therefore, this thesis will speak about basic informations and concepts, that are connected with topic. Informations about the target group of people, job description and inadequate working position of different body parts during the work are described. The next part is focused on the workplace design and measurements. In conclusions layouts of the workplace in CAD software and JACK human simulation software with analysis OWAS and RULA can be found. OWAS and RULA analysis assess the working position during work.

1.1 Literature Research

This work focuses on the design of the work desk, space under the table level and around. The output is modeling of layout in the human simulation program JACK with posture analysis. Specifically studies of design associated with the simulation program JACK are limited.

Similar studies are focused on the needs of each country and only with the equipment for the local market, as is it in the case of the study `Ergonomic of VDT workstations for wheelchair user[15]` or on the anthropometric characteristics of people, in studies `An anthropometric study of manual and powered wheelchair user[13]` and The comparisons of anthropometric characteristics among four people in East Asia and many others. Regarding to the poor posture during a work, informations was taken from a study `An analysis of work postures of manual wheelchair users in the office environment[6]`.

2 General Information

This section will focus on the definitions of important terms and definitions related to this work.

2.1 Disability

There are several ways to formulate the definition of a disability. Most frequently mentioned are medical and social models[3].

The medical approach relies the fact that disabilities are an individual problem defined from the lack of health from diseases, injuries, etc. It is based on the method of solutions, which are seen primarily in medical rehabilitation.

The social model offers a somewhat different approach. This model understands disability not as an affair of the individual, but as a relationship between individuals and their surroundings. Disability is not a lack of health itself, but is only the result of barriers between the individual and the surroundings, regardless of their physical nature (eg, unsatisfactory workplace) or social (eg, rejection by society). These barriers make it impossible for a person to perform the activities of daily life. The objective of the work with a disabled person is then primarily identifying and removing these barriers. As will be evident from the following definitions performed in the most recent

international documents, the social model has become prevalent in the modern understanding of the concept of disability[3].

I will define those points based on the international definition of disability, which defined by the World Health Organization (WHA) in 1980 in a document entitled International Classification of disorders, disabilities and handicaps (ICIDH):

- *Impairment* is defined as a functional, organ loss or abnormality of the body,
- *Disability* is the limitation or loss of perform certain activities or practices that can be considered as usual or normal,
- *Handicap* limitations is of a social nature that a person is experiencing as a result of their disability. It is therefore a dimension of the relationship between disabled people and their surroundings.

Between the different terminology a relationship exists, because from a disorder may develop an impairment, which may lead to the formation of a disability. ICIDH marked a significant shift to the unification of the concepts of disability[3].

2.2 What is 'Wheelchair'

Wheelchair is a device used for mobility of people for whom walking is difficult or impossible because of illness or disability. Wheelchair is usually made up of the seat which is supported by two large wheels on an axle attached to the back of the seat and two small wheels at the feet.

- Individual parts of a wheelchair

In Figure 1 below you can find a description of the parts of wheelchair.

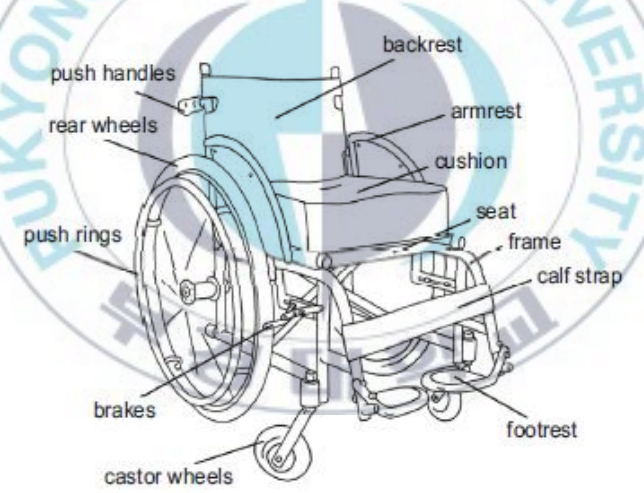


Figure 1. Parts of wheelchair [1]

2.3 The Basic Terms

These are some important terms from Korean law which are used in this study.

1) Disability

An impairment or loss of physical or mental functions that substantially limits an individual's persona for social activities for extended period[(4)].

2) Persons with disabilities

Those who because of physical or mental handicap, are subject to considerable restriction in their working life for a long time, as more fully defined in the Presidential Decree[(5)].

2.4 The List of Laws and Organizations in South Korea

1) *Act on Employment Promotion and Vocational Rehabilitation for Disabled Persons,* Act No.4219, Jan. 13, 1990

This law promotes the employment and vocational rehabilitation of persons with disabilities that even though their difficulties have a chance to live a decent life.

2) *Anti-Discrimination against and Remedies for Persons with Disabilities Act*, Public Law No. 8341, April 10, 2007

3) *Enforcement Decree of the Anti-Discrimination Against and Remedies for Persons with Disabilities Act*, Enacted April 10, 2008, Presidential Decree No. 20766

The purpose of this Enforcement Decree is to prescribe matters delegated by the Act on Employment Promotion and Vocational Rehabilitation for Disabled Persons and those necessary for the enforcement this regulation[7].

2.5 Entities Dealing with People with Disabilities in the Labor Market

Authorities that enforce the rights of disabled people in the labor market. These are the major organizations that are most important here.

1) *State and Local Government*

This institution deals with questions relating to the welfare of local residents and they accept provisions relating to local regulations. It also deals with administrative matters, selection of local taxes and fees for various services. Any lower level local government has several districts that serve as offices for the needs of its inhabitants. These offices deal mainly with routine administrative and social services[7].

2) *Ministry of Health, Welfare and Family Affairs*

At the Ministry of Health, Welfare and Family Affairs there is an office which deals with persons with disabilities. There are three available teams in the department, which can provide assistance to disabled people.

3) *Ministry of Employment and Labor*

Establishment and coordination of employment policies and strategies. Includes solving discrepancys in the labor market through advanced employment service programs, they provide job security for the prevention of unemployment and employment support, and they seek to create more decent jobs based on labor market analysis and implementation of social service program work[8].

4) *Korea Employment Agency for the Disabled*

It creates jobs suitable for people with disabilities and provides support to companies that employ people with disabilities. Continuous improvement of policies and systems so that South Korea can become a leading country in terms of employing disabled people[9].

3 Disability and Integration into Working Process

3.1 Classification of Disability under the Law

Types of disabilities and standards used to identify individuals as persons affected.

- Physical disability
- Neurological disabilities / brain disorder
- Sensory disability (vision impairment)
- Sensory disability (hearing impairment)
- Communication difficulty (speech impairment)
- Mental retardation
- Psychiatric disability (developmental disabilities)
- Psychiatric disability (mental illnesses)
- Kidney failure
- Heart failure

As this work relates to the job designed for active wheelchair users, so additional text is connected on the physical disability[10].

3.2 Defining of the Target Group of Users for Jobs

The limitation of movement is created on the basis of inheritance, illness or injury. Further motion defects are divided into:

1) congenital (hereditary)

2) obtained

All motion defects could have various scales and degrees of damage. Acquired motion defects include "Paralysis of the spinal cord."
This is a serious handicap, which arises from a disease (hereditary, congenital), but also can arises from the spinal injury with spinal cord damage (sports, traffic accidents etc)[(11)].

If some of the ventral roots of the spinal nerves are injured that leads to weak paralysis without feeling or sensitivity. An important factor is whether the spinal cord is affected partially or completely, but also in which part is the spinal cord damaged.

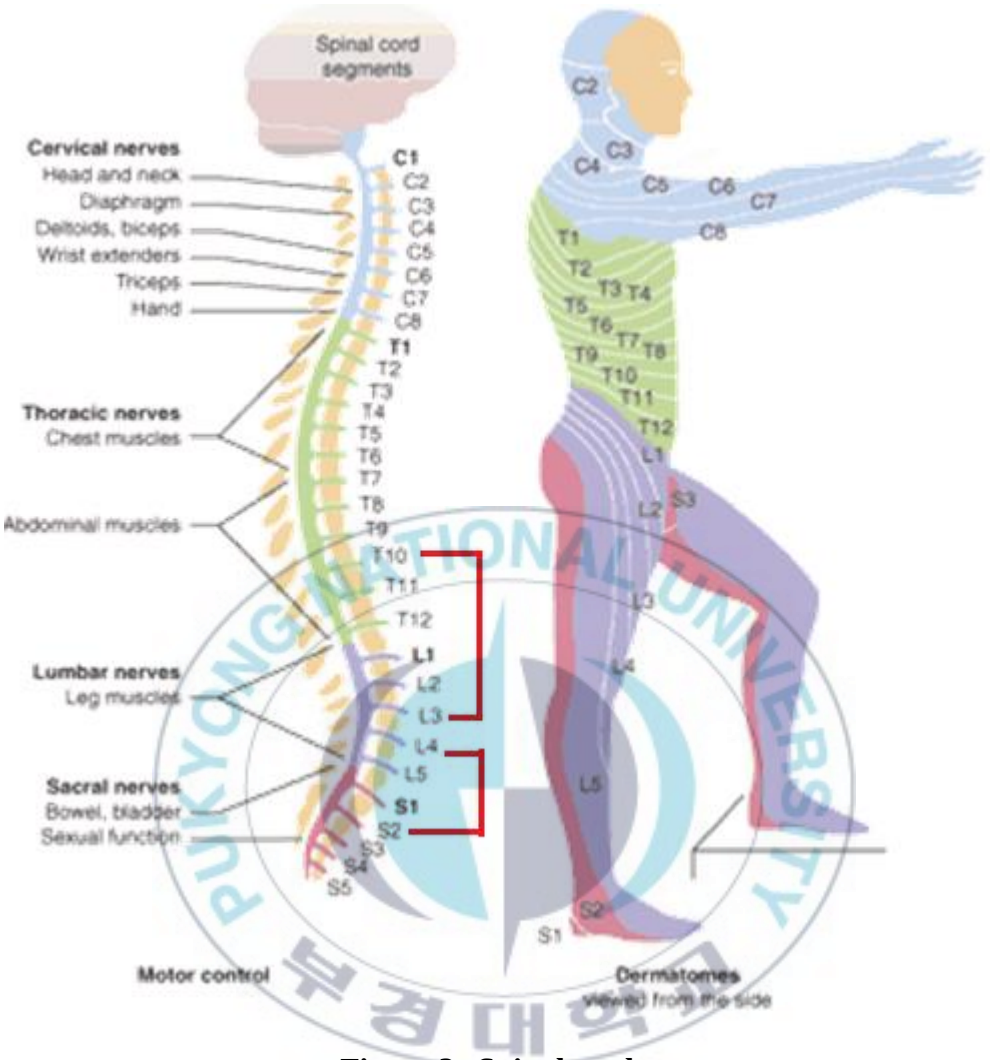


Figure 2. Spinal cord segments

From the perspective of degree of mobility and independence of people with spinal cord injury in T10 - L3 and L4 - S2 (Low paraplegia and paralysis) was defined. These people have partial or complete loss of mobility of lower limbs. Disabled persons have preserved sensitivity from the torso to up and some people have the ability to feel the lower abdominal muscles. The upper

body is in good condition, when people can sit without support, leaning in all directions, turning the torso. Their reflexes and work with objects is unlimited[12]. Most of these disabled people are active and independent. The most affected groups are young people and middle aged people, where the injury was caused by an accident or a fall from a height.

For these people, this is a life changing and demanding experience and therefore it is necessary to give them the quick chance of smooth reintegration into society and especially into professional life.

3.3 Characteristics of the Job Description and Workplace for Employees

The task of the administrative employee is to provide a wide range of office-support activities. His work activities include rewriting, inserting data into computer through a database or spreadsheet editors or other computer based work. Other activities could be, handling correspondence (including packages), regulations, decrees, laws and regulations and finding records, recording meetings and negotiations, including the preparation of necessary documents and information, implementation operative tasks, ensuring's administration and record-keeping tasks of the organization department and monitoring of deadlines and their fulfillment, organizing visits, meetings and seminars.

A prerequisite for the successful performance of this occupation are administrative skills, fast typing on keyboard using computers, especially text editors, knowledge of spelling rules and the rules for editing correspondence and postal service. Furthermore, concentration, good memory, patience, reliability and accuracy.

3.4 Ergonomic Principles for the Workstation

The work area is a spatially defined area of the workplace where workers carry out their work activities. Devices, their properties, materials and work process, specifies the requirements for workers with regard to their working position, movement and mental, sensory, physical entitlements. Ergonomic adjustment to prevent health damage in the workplace usually don‘t constitute major economic costs, but the benefit in the long term is considerable (reduced morbidity, prolonging productive age) and also contribute to a sense of work comfort. Ergonomic design of a workplace will respect anthropometric, physiological, hygienic and psychophysiological requirements. The goal of the ergonomic arrangement of the work desk is to create an effective workplace to avoid disproportionate workloads to a musculoskeletal system (unsuitable working positions, unilaterally and long-term loading of muscle groups causes the occurrence of fatigue, sensation of discomfort, etc.)[2,16,20].

4 Analysis of Work Postures

This section introduces office environments, poor posture, and why it is appropriate to use back cushion.

4.1 Office Environments

At the moment, when a person in a wheelchair starts to use a work desk, his/her space requirements are different from the requirements of a healthy person. So the design of work desk for a healthy person may not be suitable for a person in a wheelchair. It is necessary to appropriate design modifications and prescribe devices needed in the workstation. In the end it is also important to provide modifications that may be required in the office and common areas.

Despite a suitably modified workspace, difficulties may occur, which may cause problems for these workers. These are:

- Cannot perform work activities for more than 4 hours per day
- Tire easily
- Sensation of physical discomfort[13]

The groups of people to whom this work is focused on feels discomfort during filling out and writing documents in the area of the lumbar spine, upper back, erector spinae, trapezius, rhomboideus, levator scapulae.

4.2 Poor Posture

Poor posture and poor positioning of the other parts causes the formation of long-term health problems and the related absence from work. Therefore it is very important to properly set a workspace for your total working comfort[13]. In sitting, most of the body weight is supported by the buttocks, particularly through the ischial tuberosities. Pressure at these points is enough to occlude sufficient blood flow to the overlying skin, causing tingling, numbness, and discomfort. As a result, if the person is able, weight is shifted off these body parts to allow blood flow to resume[21].

Table 1. Poor body positions and painfull area of the body

POOR BODY POSITIONS	POSSIBLE OCCURRENCE OF PAIN
Sitting without lumbar support	Lumbar region
Sitting without elbows rested on a working surface that is too high	Trapezius, rhomboideus and levator scapulae muscles
Sitting without good footrest of the correct height	Knee, legs and lumbar regions
Arms reaching upward	Shoulders, upper arms
Maintenance of any joint in its extreme position	The joint involved

4.3 Wrist

When working with a keyboard and mouse, it is possible to cause wrist injuries. Therefore, we must prevent wrist bending mainly in the ulnar deviation and palmar flexion, which causes diseases such as carpal tunnel or tenosynovitis[16].

4.4 Shoulder and Upper Back Problems

Problems in this area are caused by performing work above the elbow level. The worker usually flexes the elbows or elevates and abducts the shoulders to be able to handle the work. For desk work, a shoulder abduction angle of 15 to 20° or less and flexion angle of 25° or less should be attempted[21].

4.5 Neck

Discomfort in this area is often caused by increased muscular activity required to support the head while it is craned over to focus on objects on a flat surface[22]. Working spaces should be designed so workers can easily change position and reduce muscular activities in areas associated with sprain in the neck area.

4.6 Back Cushion

Since even a healthy person has a problem keeping the back in the correct position, this is also a problem for a person in a wheelchair. Workers confined to a wheelchair for the duration of their work have no chance to relax by changing position, standing up or sitting differently. There is a high probability that the individual subconsciously copies the shape of the back of wheelchair with his back, and so the risk of occupational diseases while using conventional wheelchair is probable.

Therefore is recommended to apply lumbar pad in this study that provides comfort for the lower back. It is designed to reduce back pain and muscle tension during the work.

Figure 3. Example of back cushion

5 Measurement

In the beginning of this section you can find a description and dimensions of the wheelchair and other part is focusing on the measurement.

5.1 Wheelchair Used in this Study

Wheelchair specifications needed for this study were obtained from ISO (International Organization for Standardization)[14] and for measurement, a conventional wheelchair in Figure 4 made by Daese company was borrowed.

Finding a wheelchair that fits the physical, lifestyle and financial needs of the user is long process, since obtaining a properly fitting wheelchair can often take three-to-six months and many clients simply do not have the financial resources to obtain the 'ideal' wheelchair. Choice of a wheelchair is a very individual and personal decision. Most people with an injury below C6 (cervical nerves) can handle manualy operated wheelchair and some individuals with a C6 injury can as well. It is suitable to use this kind of wheelchair, because it has standard parameters. Otherwise the level of desk can be adjustable as necessary.

Figure 4. Wheelchair

5.2 Wheelchair Description

The following is a description of the wheelchair which was used for this study

1. The front wheels of this tubular wheelchair are pneumatic wheels that absorb shock very well during movement.
2. It is equipped with an easy-to-clean leather seat so it can be used in a sanitary manner.
3. The equipped toggle (lever type) brakes will stop and prevent any slipping.
4. It has high durability due to its steel frame with high strength.
5. The wheelchair can fold-up and store easily.
6. The height of the footrest can be adjusted to suit your body shape[18].

5.3 Dimensions of the Wheelchair

Figure 5 shows pictures of the wheelchair from different angles with a description of dimension.

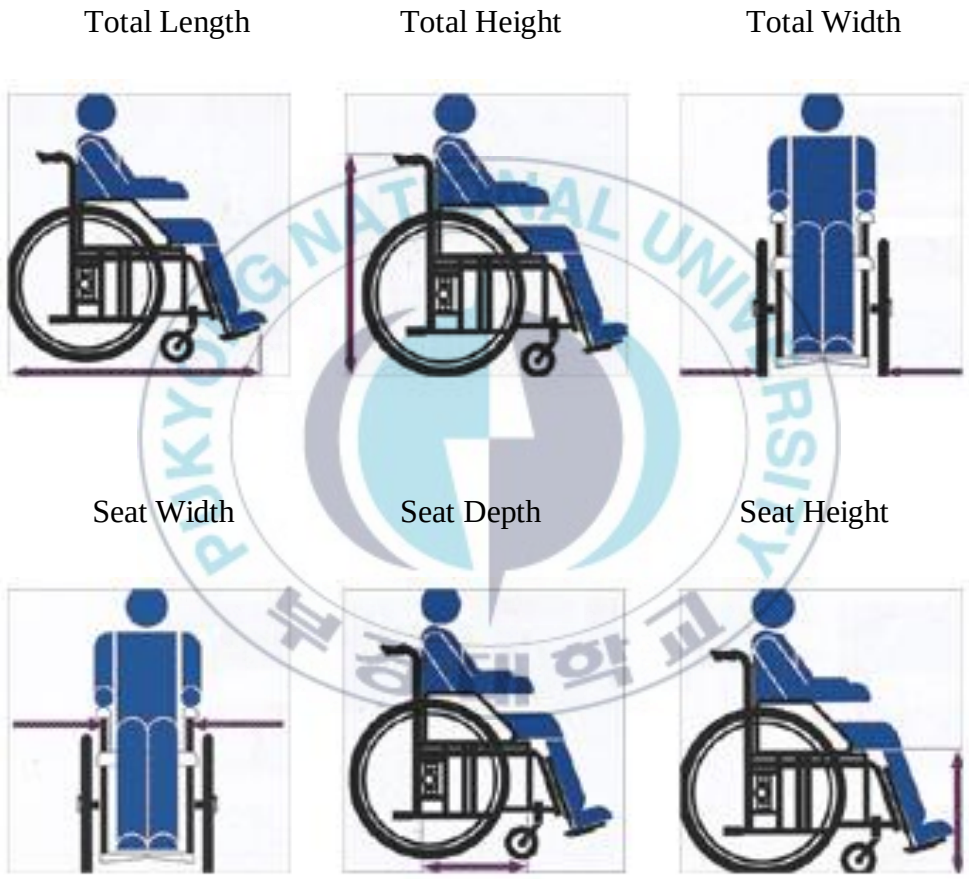


Figure 5. Dimensions of the wheelchair

Table 2 contains 6 dimensions of the wheelchair in millimeters that are shown in Figure 5 above.

Table 2. Dimensions of the wheelchair

DIMENSIONS	[mm]
Total length	1050
Total height	870
Total breadth	620
Seat height	460
Seat breadth	410
Armrest height	710

5.4 Process of Measurement Research:

Measurements were taken from 30 volunteers between the ages of 20 and 30 years. Overall 17 measurements were taken from each volunteer for this study. It is important to mention that all distances were measured with healthy people. For this workplace it is important to be able to work with upper part of body properly, as people with paraplegia and paralysis are, so to simulate the extreme conditions and meet the real situation there was no problem to use measurements of healthy people as a subject. Tables 3, 4, 5 ,6 shows individual measurements in centimeters.

Terms explanation

Stature – total height of the person

Weight – total mass of the person

Shoulder Breadth – shoulder width from center to center of the shoulder bones

Shoulder Height (seat) – shoulder height from the seat

Reach of Palm – length of the hands to the center of the palm

Reach of Fingers – length of the hands to the end of the fingers

Reach of Arm (outstretched) – length of the hands to the center of the palm in extension (25 cm from the rest)

Knee Height – knee height in sitting position

Popliteal Height – leg height to the level of the knee popliteal

Height of Eye (seat) – eye height measured from the wheelchair seat

Overlaps of Feet – the length of the foot overlap on the footrest

Length of the Forearm (palm) – length of the forearm to the center of the palm

Length of Thigh – length from the back of the buttocks to the end of the knee

Average – the average value of all measured values

SD - average deviation character values from their arithmetic mean

Median - numerical value separating the higher and lower half of a data sample

Table 3 shows the body measurements, which are stature, weight and shoulder breadth. At the end of the table is average, SD and median of those three body measurements.

Table 3. Measured values (part 1)

Measurement	STATURE	WEIGHT	SHOULDER BREADTH
1	183	79	32
2	185	77	30
3	181	79	30
4	180	81	38
5	173	64	38
6	165	60	32
7	172	68	34
8	177	69	35
9	176	77	32
10	171	70	32
11	172	73	33
12	173	95	35
13	165	60	32
14	180	73	33
15	179	71	31
16	167	72	34
17	172	60	33
18	168	62	30
19	168	94	31
20	173	62	32
21	173	70	30
22	178	80	30
23	171	72	33
24	186	57	33
25	171	80	34
26	177	64	32
27	170	63	30
28	172	58	30
29	178	82	31
30	161	56	30
Average	173.90	70.93	32.33
SD	6.05	10.15	2.19
Median	173	70.5	32

This Table shows the body measurements, shoulder height from seat, arm reach to palm and reach of arm reach to fingers.

Table 4. Measured values (part 2)

Measurement	SHOULDER HEIGHT (seat)	REACH OF ARM (palm)	REACH OF ARM (fingers)
1	58	73	86
2	67	72	86
3	65	73	86
4	65	74	89
5	57	66	80
6	57	66	80
7	59	68	83
8	57	72	87
9	67	73	86
10	58	71	85
11	63	67	80
12	59	69	81
13	55	68	92
14	60	70	84
15	58	69	84
16	57	66	78
17	56	72	86
18	56	63	75
19	59	70	83
20	58	70	85
21	56	71	85
22	63	75	90
23	53	64	79
24	60	71	87
25	57	68	81
26	62	75	83
27	56	66	80
28	59	66	79
29	62	69	83
30	56	69	79
Average	59.17	69.53	83.40
SD	3.58	3.17	3.86
Median	58	69.50	83.50

Table 5 shows: other body measurements such as reach of arm (out stretched), knee height and height of popliteal.

Table 5. Measured values (part 3)

Measurement	REACH OF ARM (out stretched)	KNEE HEIGHT	POPLITEAL HEIGHT
1	106	76	59
2	105	74	60
3	100	70	65
4	104	75	60
5	100	72	58
6	103	67	54
7	102	72	59
8	107	71	57
9	101	73	59
10	110	70	58
11	100	68	65
12	100	72	59
13	99	67	56
14	107	74	63
15	108	76	60
16	105	69	58
17	112	75	62
18	102	70	57
19	108	52	52
20	110	62	62
21	106	72	60
22	111	64	55
23	108	71	57
24	111	75	63
25	107	71	57
26	107	72	61
27	104	69	59
28	99	71	62
29	105	73	62
30	102	64	54
Average	104.97	70.23	59.10
SD	3.88	4.92	3.17
Median	105.00	71	59

Table 6 shows the height of the eye measured from the seat, overlaps of the feet, length of the forearm from the elbow to the palm, and the length of the thigh. All body measurements are also in centimeters.

Table 6. Measured values (part 4)

Measurement	HEIGHT OF EYE (seat)	OVERLAPS OF FEET (on footrest)	LENGTH OF THE FOREARM (palm)	LENGTH OF THIGH
1	79	14	34	49
2	83	12	33	45
3	77	12	33	46
4	75	14	35	44
5	73	11	35	41
6	73	12	32	44
7	74	12	31	45
8	75	13	34	49
9	72	13	34	46
10	73	13	34	43
11	76	14	32	41
12	74	14	35	40
13	69	12	32	39
14	79	15	34	42
15	73	13	36	42
16	73	13	32	38
17	72	14	34	44
18	71	14	33	41
19	75	15	32	41
20	76	15	33	43
21	73	15	33	45
22	82	14	32	41
23	69	14	33	43
24	80	15	34	43
25	74	12	31	43
26	79	12	33	42
27	73	12	32	41
28	72	13	32	43
29	76	16	32	47
30	74	14	32	38
Average	74.80	13.40	33.07	42.97
SD	3.42	1.25	1.26	2.77
Median	74	13.5	33	43

5.5 Establishment of a Separate Proposal of Workplace

This section focuses on the information about the design of the equipment used in this study. What kind of equipment and the dimensions of each one that were used and where there are in the design and why.

5.6 Information about the Models of Equipment Used in this Study

For this work desk accessories have been selected, which are widely available on the market. For example a computer monitor, which is also the PC case. Ergonomic keyboard and mouse, which are placed on the work desk for convenient access and movement around the desk. The initial proposal was to have a sliding drawer under the desk level, but it was changed because the armrests on the wheelchair are to high which caused problems while sitting at the desk. The phone is placed next to the monitor on the left side to be easy to use and comfortably work with the mouse or keyboard at the same time. The printer is located on the left side of the worktop because of occasional use, but also within convenient reach. The document holder was placed between the keyboard and PC monitor. The worker does not need to strain their neck by turning to the side and at the same time he is able to see the monitor without problems. The noticeboard is located on the right side of the working area on the adjacent wall.

All equipment is placed to make the best fit for the user's convenience during work.

5.7 Design of Workstation

The design of the work desk is designed so that the space is suitable for wheelchair users. The proposal provides a space to turn with a wheelchair and also more space at the work desk and space around the desk itself for easy movement around the table.

The main task was to consider the dimensions of the workplace, and suitably design the other components for everyday use. The process of the proposal itself is described below. The worktop is L shaped. This is for easier wheelchair movement and also provides a larger area, which splits the table into a main and secondary area. The main area is intended for work on the computer and secondary area allows comfortable work for occasionally filling of documents or work without computer on the left side of the table. This type of worktop allows smooth and not more than necessary movement during work and sufficient space for placing of many other components. Worktop height is adjustable within a 75 cm to 86 cm range. The worktop has a thickness of 3 cm. The length of each of the sides are as follows: Right side is 125 cm long and adjacent thickness of the rear edge is 15 cm. Rear edge has a length 191,5 cm and the left part of the table length is 65 cm. The shelf is attached to the

rear edge, which is on the left side of the workspace and dimensions are 100 x 20 cm. It is located at height of 17 cm from the worktop. This space can be used for the storage of documents. Under this shelf is the area where the printer is located. Designed for possible use at the end of the table on the left side.

In the main area are a monitor, keyboard, mouse and phone. Dimensions of keyboard are 51 x 26 cm and is placed on the worktop directly to the center of axis of the occupant. So that the palms of the hands are well placed on the keyboard while forearms are in the main work zone. The average reach is 33.7 cm. When the hands are outstretched the palms reach a distance of 69.5 cm. The phone is located in an outreach zone on the left side of the monitor and dimensions are set at 15 x 20 cm. The mouse lies in main access zone on the right side of the keyboard. The monitor is within a stretching reach of the fingers directly opposite from the person at the distance of 83 cm. So the person is able to optionally turn on / off the screen. It is designed to be 42 cm high from the table top. The monitor size is 45 x 30 cm and it is recommended to be height adjustable from the tabletop. The screen can be positioned at different angles. The function of the adjustable tilt angle may provide a means to meet the ergonomic demand of the workers with different statures[15]. Between the keyboard and the monitor is the place for the document holder, which has dimensions of 32 x 15.5 x 11.2 cm. In the proposal the noticeboard

is has dimensions of 60 x 32 cm. It is placed at height of 6 cm above the tabletop and 10 cm from the sidewalls.

5.8 Comparison between Wheelchair and Non-wheelchair Worker

Even though this table was design to be adjustable for the healthy worker as well, it is necessary to mentioned differences between table for healthy and disabled person, especially the space under the table. Table 7 shows informations about different dimensions.

Table 7. Differences: wheelchair and non-wheelchair worker

	Healthy worker [mm]	Wheelchair user [mm]
Adjustable height	680 - 760	750-860
Deep at knee level	440	430
Deep of foot level	600	650
High at the foot	100	110
Breadth of seat	520	620
Turning radius	Not specified	750

For easier and better movement from door to work table, this workplace should be placed close to door area. No obstacles and barriers on the way to the work table.

6 The Layouts of the Workspace in the CAD Program

To better demonstrate the overall look, layout of each tool, reaches of workers and final work with human simulation JACK program, the work desk was drawn in a CAD program. This was the first layout which helped to imagine and realize second layout in the JACK. In this section there are the individual drawings and descriptions. The design of the workplace is based on the average measured values which you can see in Table 3, 4, 5, 6, which are compared with the average values of a healthy person[17]. These values are color coded on the proposals.

6.1 The View from the 4 Perspectives

Here you have a preview of the work desk from the 4 views. Front view, left view, top view and isometric view. Each proposal includes a scale and dimensions of the various parts of the work desk. As mentioned above, in this work desk you can find computer, keyboard, mouse, phone, documents holder, printer, storage space and noticeboard.

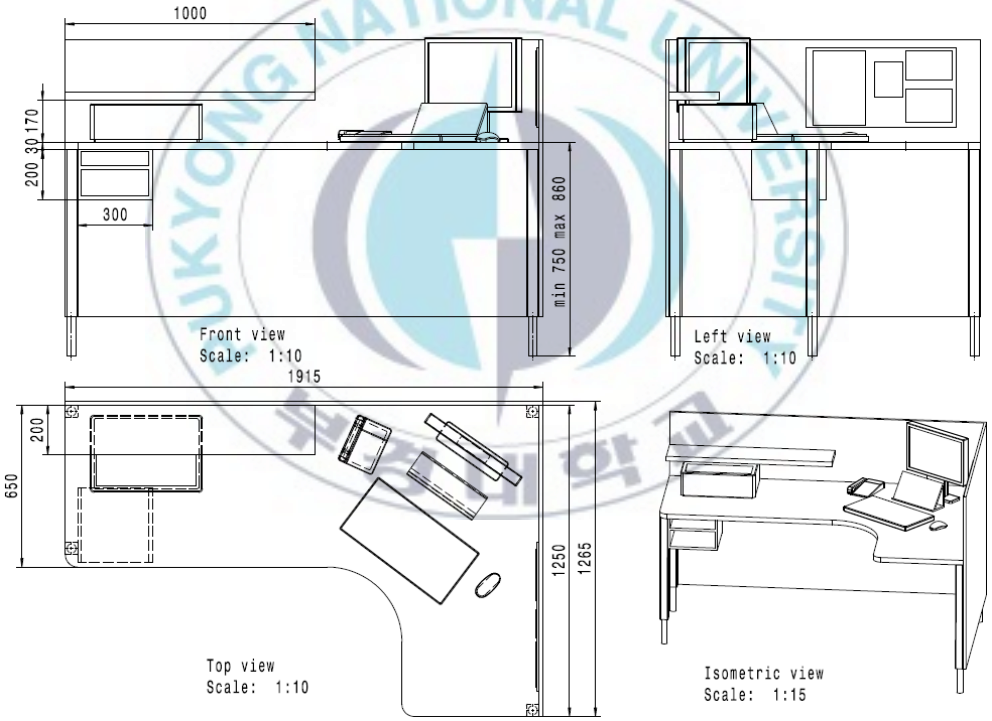


Figure 6. The view from the 4 perspectives

6.2 Reach of a Wheelchair User (main area)

On the top view in the main work area is drawn the users reach, which is a priority for working on the computer. Reach of the forearm to the palm is 33.7 cm. The worker is able to work comfortably with the keyboard and mouse, which are plotted in the normal area[16,20]. The reach with the hands outstretched is a distance of 69.5 cm. In this range, the worker has a phone, document holder and noticeboard comfortably available. This equipment mentioned above are in the maximum area[16,20]. In this case the worker may not reach the entire printer. Within 83 cm reach of his fingers, the worker is able to turn on / off the monitor screen. There is also a turning radius drawn, which is 75 cm. Additionally three dimensions of the person are shown in the diagram. First is 62.3 cm which is distance between the elbows of the person. Second is 32.3 cm which is the distance between the shoulders and the last dimension is the distance between the level of the elbows and the level of the shoulders.

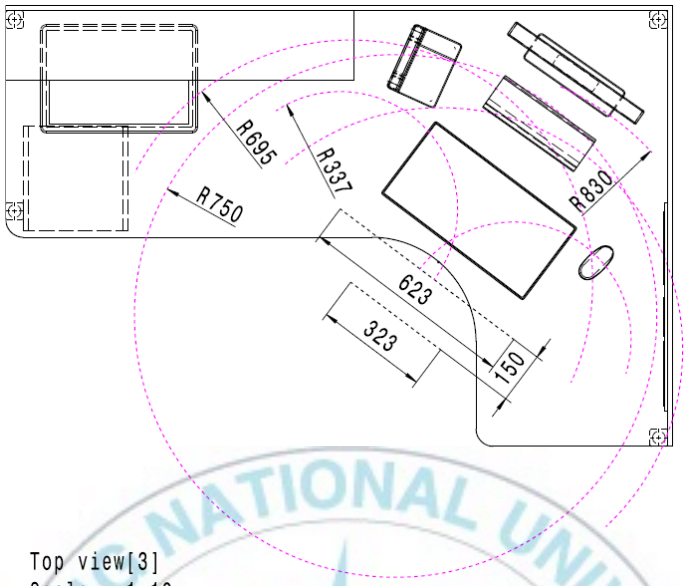


Figure 7. Reach of a wheelchair user (main area)

6.3 Reach of Wheelchair User (secondary area)

This is the plotted reach when a person works in the secondary area. All reaching distances are the same as in the previous layout. In this position, the worker is able to use the printer and extendable drawers on the left side of the table.

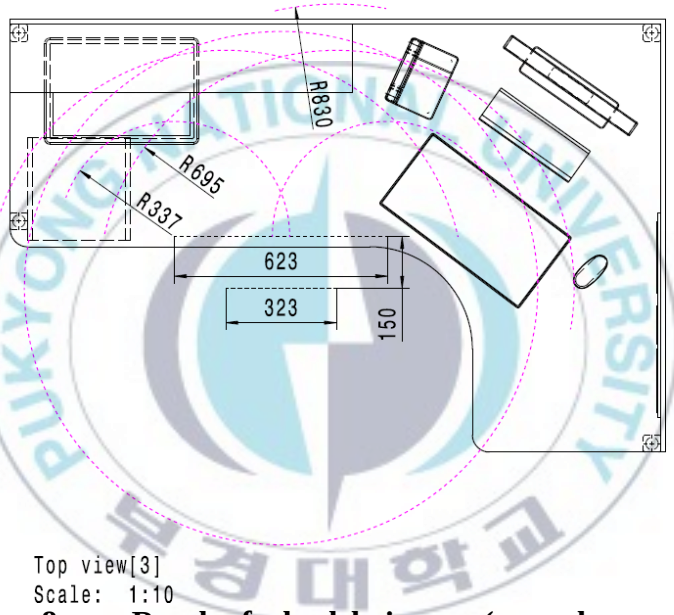


Figure 8. Reach of wheelchair user (secondary area)

6.4 Comparison of Reaches

In the last two drawings you can see 2 colors ranges. Pink is the reach of person in the wheelchair and blue is for a healthy person. The reach of a person in a wheelchair is the same as in the first drawing. The reach of the forearm of a healthy person in this case is 32.1 cm and at the outstretched hand range is 65.3 cm. As seen from the drawings, a person in the wheelchair has about 1.6 cm longer reach forearms and 4.2 cm longer range when hands are outstretched. This difference may be due to small inaccuracies in the measurement of wheelchair users and may also be from inconsistencies in the database of the measured values, which were gathered from internet research.

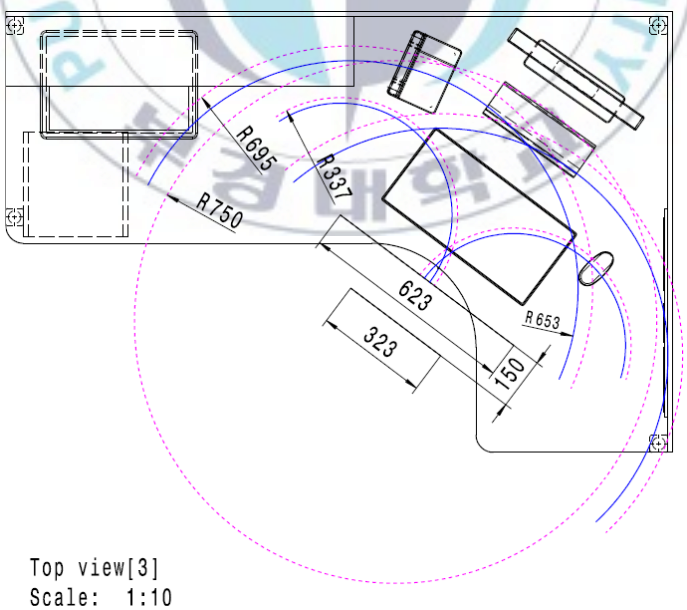


Figure 9. Comparison of reaches

7 Jack Human Simulation and Ergonomics Analysis Software

7.1 Introduction

Jack is a complete system for generating 3D environments of ´virtual worlds´ and interacting with them in a graphical environment.

In Jack simulation software you can: create, visualize, and analyse human factors in design, evaluating maintenance operations and studying humans in the ´simulated workplace´[19].

7.2 Overall Appearance of Layout

Figure 10 is a view of a workplace as a whole, which we will be discussed in greater detail later.

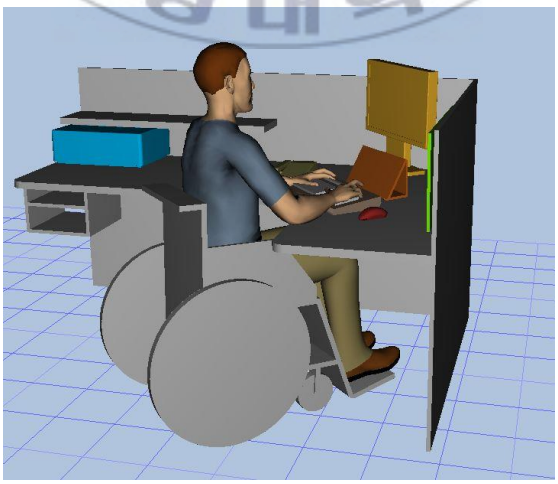


Figure 10. Overall appearance

7.3 Equipment

To be able to work with JACK simulation software, all equipment such as table, printer, PC, document holder, keyboard, mouse, note-board and also wheelchair where drawn in CAD software and imported to JACK. For imported files IGES 5.3 format (.igs) was used. All the equipment which you can see in Figure 11 has the same dimensions as on the layouts from the CAD drawings.

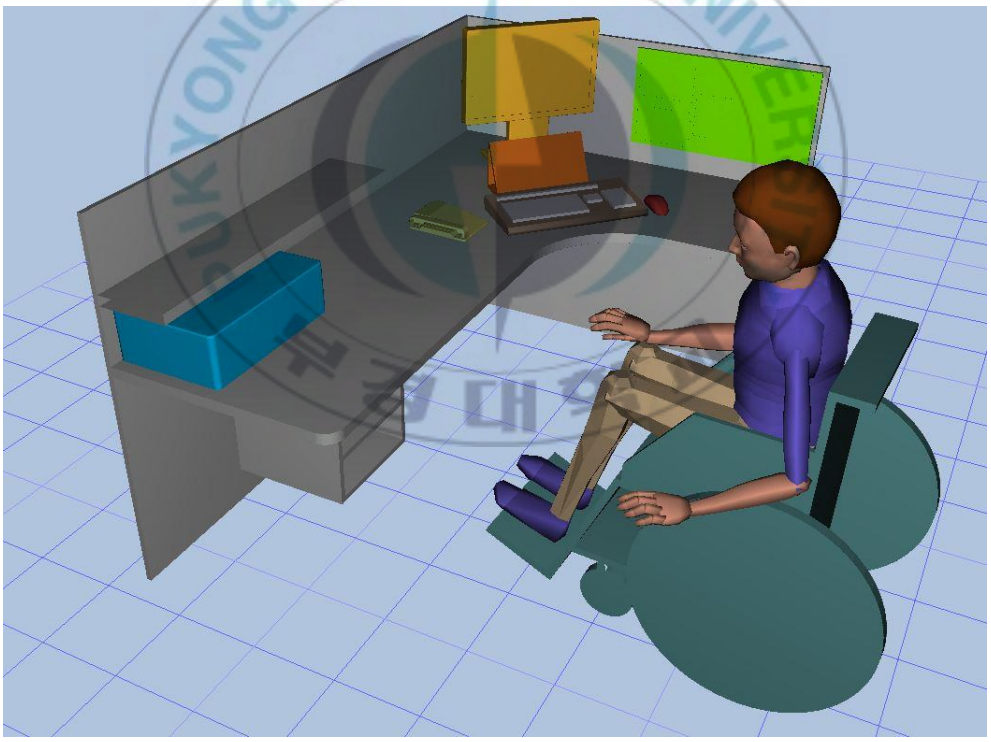


Figure 11. Equipment imported to JACK

7.4 Adjustments that had to be changed

1) Height of footrest

Since the wheelchair was borrowed the footrests had been set too high (14 cm above the ground), after transfer to Jack simulation software it was not possible for a person to enter the workplace with a wheelchair, as their knees were too high. Therefore, the footrest was lowered 4 cm and this made enough space for entry under the table and extra space for any movements. Normally the footrest is higher to allow ease of use outside of the workplace.

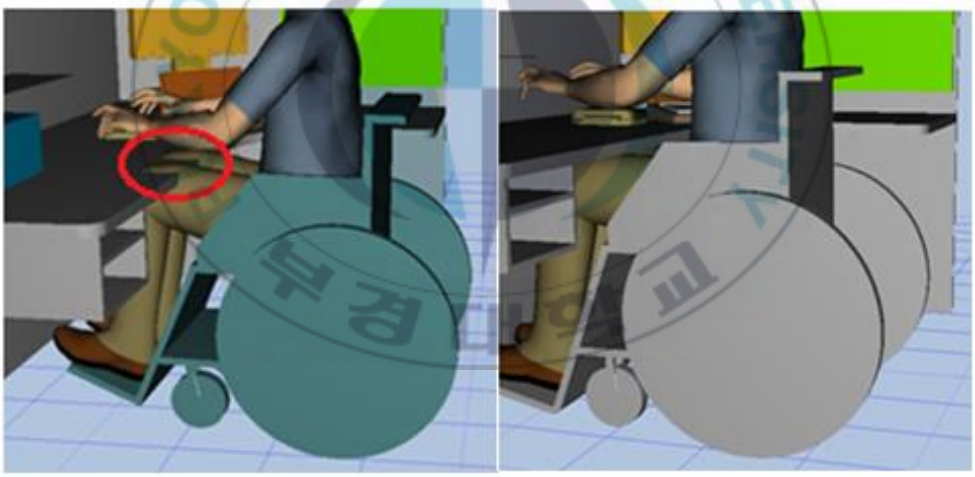


Figure 12. Before and after adjustment of wheelchair

2) Increased support for the forearm

To relieve the upper limbs and for better working comfort a chair should have armrests (in this case a wheelchair). Unfortunately, the armrests of this wheelchair were too high, as you can see in Figure 13, therefore it was not possible to use it comfortably, without straining the upper limbs. Another negative is the fact that the wheelchair can not be pushed deep enough under the table because of the armrests. Since the table is height-adjustable (750-860 mm), it was necessary to increase the level of the table to match with the analysis of the worker.

Figure 13. Height armrest

3) Problem with measured values

During the transmission of the measured values of people to create a character in JACK some problems arose. According to the data set I collected it was impossible to create a character in JACK simulation software because of its presets. Thus when body shaping started this person started to deform and the embedded information began to transcribe. For that reason the simplest way to continue was to choose a Asian character (95th percentile - 178.1 cm and 76 kg), which is slightly higher than my measured values (173 cm, 70.5 kg). Because the height is different between median I measured and the character I chose from Jack software is not big all the reaches and other important outcomes will fit my measured data set as well.

7.5 Reaches

In the pictures below the reaches for both hands are shown for the two possible positions (working with PC and filing the documents). In the Figure 14, you can see the worker's reach and therefore where is he able to work comfortably without straining himself.

7.6 Main Area

In the working position in Figure 14, the worker is able to work comfortably on the keyboard and mouse, use the phone or note-board and he can turn on / off the PC screen. The picture shows the distance between eyes and monitor, which is 64.48 cm. It should be noted that the upper edge of the screen is at user's eye level.

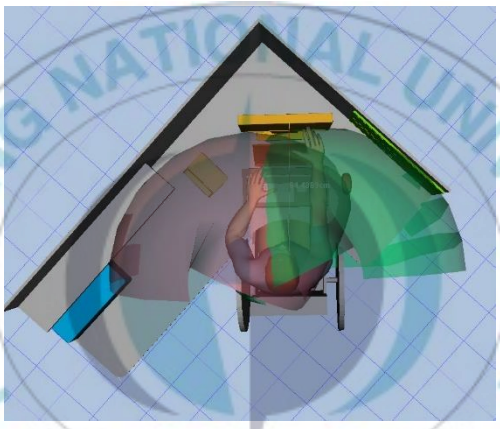


Figure 14. Reaches of left and right hand 1

7.7 Secondary Area

Figure 15 shows the reaches with hands outstretched. In this working position the worker has space for writing and filling in the document storage, using the printer and his reach enables him to use the shelf in front of him.

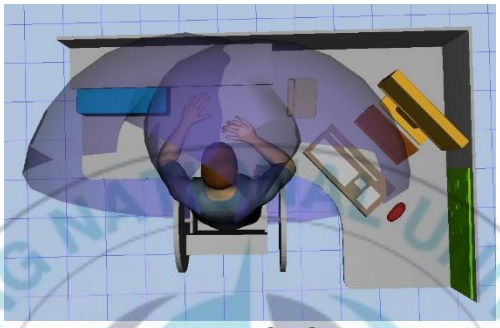


Figure 15. Reaches of left and right hand 2

7.8 Analysis OWAS and RULA

For assessing suitability of this workplace OWAS and RULA analysis were used. Individual analysis was used for both possible working position.

1) Ovako Working – Posture Analysing System (OWAS)

OWAS identifies the most common work postures: back, arms, legs and weight of load handled. Whole body posture is described by this body parts with four digit-code. These postures have been classified into four action categories indicating a need for ergonomic changes which Table 8 shows.

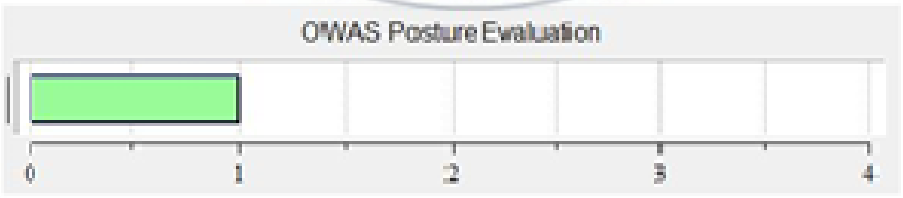
Table 8. Final OWAS score

Final Owas Score	Requirements for Action
1- Normal posture	No intervention required
2 – Slightly harmful	Corrective action should be taken during next regular review of methods
3 – Distinctly harmful	Corrective action should be taken as soon as possible
4 – Extremely harmful	Corrective action should be taken immediately

1) Both working positions

Both working positions are given a score of 1 by the result of the analysis. The work posture seems normal and natural. The postural load on the musculoskeletal system is acceptable. There is no need for corrective measures.

Figure 16. OWAS result



2) Rapid Upper Limb Assessment (RULA)

This technique was designed to quickly and easily assess the workload from the working posture. Analysis focuses on the shoulders, wrists, neck and upper limbs.

Table 9 shows final evaluation of RULA analysis. Score from 1 until 7 with requiirements for every action.

Table 9. Final RULA score

Final Rula Score	Requirements for Action
1 or 2	Indicates that posture is acceptable if it is not maintained or repeated for long periods
3 or 4	Indicates that further investigation is needed and changes may be required
5 or 6	Indicates investigation and changes are required soon
7	Indicates investigation and changes are required immediately

1) Work with PC

RULA analysis evaluated that the upper part of musculoskeletal system is not over-burdened and the risk of burden due to body position is acceptable. Result of the analysis is 2. In the Figure 17 you can see hand position on the keyboard during a work with computer.

Figure 17. Hand position on the keyboard

RULA analysis results from JACK. In Figure 18 below you see Body Group A, and Group B Posture Ratings, which contain each part of the body and at the end of the table is written the score of this position.

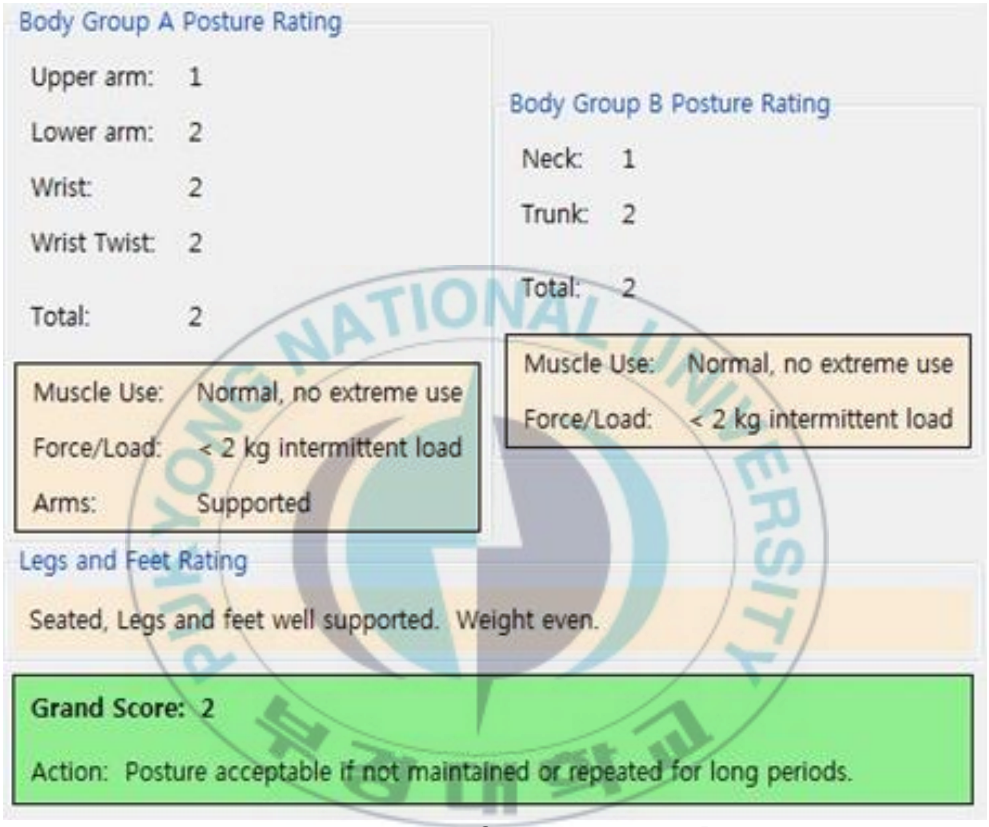


Figure 18. Result from RULA analysis

2) Filling the documents

In this position the score is also 2 as shows Figure 16. Worker will change working positions (work with PC and filling the documents) during a work shift, so he will not work in the same position for a long period. In the Figures 19 and 20 the worker is in the secondary working area. In order avoid strain to the cervical spine, the document holder was placed on a shelf in front of worker, thus allowing better posture.

Figure 19. Working position 2

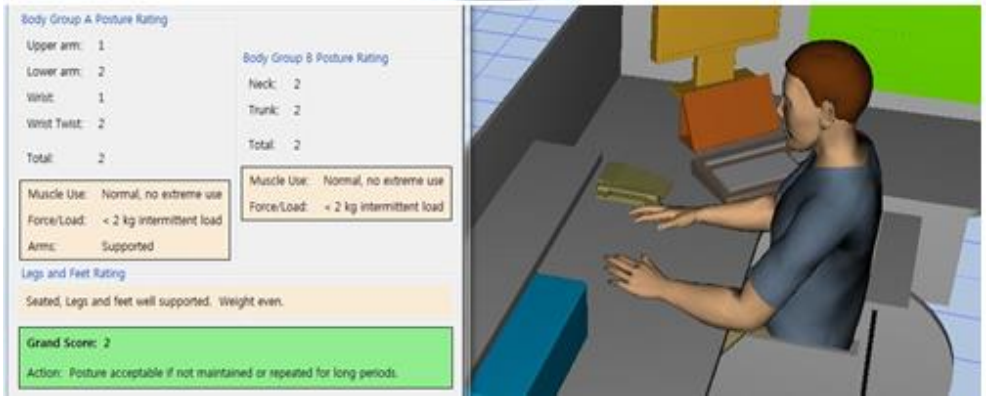


Figure 20. RULA working position

8 Conclusion

During the measurement and analysis it was found, that a work desk designed for the purposes of this work corresponds with ergonomic standards. The height of the designed table is adjustable from 750-860 mm and is large enough to allow workers to work comfortably and allowed them to smoothly move around the workplace. It is also necessary to take into account the fact that there has to be space to enable easy movement of the worker around the workspace. Because of wheelchair turning radius of 750 mm, it is necessary to have some space around the workplace, with a diameter of 1500 mm without any obstacles. A height adjustment option was considered, because of the fact that wheelchairs have different sizes and therefore fixed table height might be not suited for every wheelchair design.

According to the analysis OWAS and RULA, found in the JACK simulation program, musculoskeletal system for the person on the wheelchair is not overburdened. Results of the analysis OWAS are in both cases equal to one, which means that the position at work is natural and musculoskeletal system has a minimal burden. RULA analysis gave result of two which is acceptable when we avoid long-term workload. In this case, the employee will change working positions during working hours so long term workload will be avoided.

Analysis for worker‘s reach to the area with drawer on the left side of the table, gave results of the 3rd grade. Which means that later adjustments of work position will be required, but since this job position, relative to the main working positions for workers is not essential (in this position worker will be performing task from 1 to 2 times per shift), it is not necessary to do any further adjustments within the focus of this work.

At the end it should be noted that the wheelchair used for the purposes of this work, should be used only for short amount of time and its replacement should be considered. The armrests of the wheelchair are high, so the person in it is supported during transport and the footrest is higher than it should be, for easier navigation of obstacles and smooth movement.

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