Ergonomic Workstation Design for Science Laboratory

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ABSTRACT

The purpose of this study was to observe the anthropometric data collected compared to the existing data. Data were determined to propose the new design of chair/stool and workbench for science laboratory. The data collection samples were conducted at Universiti Teknologi MARA, Kampus Khazanah Alam, Pahang and the samples among the students in college. The ranges of ages of the samples were around 18 and above years old among the student in college who volunteer to be physically measured in this study. The sample involved 30 male students and 30 female students. Thirteen human body dimensions were measure: stature, shoulder breadth, chest depth, sitting height, sitting eye height, sitting shoulder height, popliteal height, sitting knee height, forearm hand length, sitting elbow height, thigh clearance, head length and hip breadth. Finally, the anthropometric data were compared to the previous study. The finding showed the similarity with the existing data. It proves 90% achieved the human satisfaction, example is height between 1198.78mm and 1899.91mm (show the normal distribution). Male students show the higher average value compared to females for stature, sitting height and sitting eye height. There were also mismatches between measurement of existing furniture with the anthropometry data based on seat height and seat area. Based on the data analysis, stool/chair and workbench were designed with the adjustment of the height for seat. The purpose is to give satisfaction to majority of the students.

Keywords: *mismatch, Universiti Teknologi MARA, anthropometric.*

Introduction

Anthropometry can be defined as a study of a human body dimension. Human body measurements are very different in sizes and builds. Another term that related to the anthropometry is also known as Kinanthropometry. It also studies of human size, shape, proportion, composition, maturation, and gross function, in order to understand growth, exercise, performance, and nutrition (Tsang et al., 1998).

The focus is obtaining detailed measurements upon the body composition between human anatomy and movement. It is the application of a series of measurements made on the body and from these we can use the data that we gathered directly or perform calculations using the data to produce various indices and body composition predictions and to measure and describe physique (Tsang et al., 1998). Usually, anthropometry data is very useful in designing tool, workspace design, and clothing for example in workplace design. The purpose is to make workers comfortable with their working space and prevent them from danger.

Commonly, anthropometric is related to ergonomic conditions. The definition of ergonomic is defined as the study of interactions between human beings and the objects they use and the environments in which they function. It it also concern about human anatomical, physiological and biomechanical characteristics as they related to physical activity (Anonymous, 2007).

Today, designing ergonomic workstation has become very important to reduce work related musculoskeletal disorders (MSD) such as lower back pain (LBP) especially for students whether in class or laboratory. Students were using furnitures like chairs and desks to achieve their comfortable in class. In addition, mismatch factors always happen between existing design product with the students' anthropometric dimension (Parcells et al., 1999). Then, poor posture can affect the efficiency of performance work.

Choobineh et al. (2007) stated that high rate of shoulders problem can lead to poor posture due to when used high table workstations and high rate of back problems are related to the long awkward posture and lack of back system because they not use proper backrest while working.

Literature Review

Anthropometry can help the designer with a view in the stage of the design process (Deros et al., 2009). Data collected can be used to analyze the suitable dimension of diverse range of item. Measurements are made to design a product with determined anatomical land mark or to identify a fixed point in space of dimension.

Ismail et al. (2010) reported that during class sessions, student always sit in a poor posture. Back and neck rotated while they spent long time in the classroom. Other than that, students can also get upper back pain because of the school bag's weight (weighing 3.4-4.45 kg) (Md Hamdani, 2011).

Today, the societies are facing many problems on musculoskeletal disorder and they realize that this problem is among the most costly health care (Marras et al., 2009). Marras et al. (2009) also stated that epidemiological studies indicate between 11% and 80% of lower back injuries and between 11%-95% of extremity injuries happened due to workplace physical factors.

The data collected must be a specific data and should be specifically measured. In the data collection, the information cannot be deduced from a stature, weight or a workspace (Kroemer, 2008). Data is collected based on the related positions that involves in the task to analyze the anthropometric measurements.

Table 1: The Description of Component Body Dimension

Body Dimension	Description
1.Stature	The vertical distance from the floor to the top of the head, when standing.
2.Shoulder Breadth	The maximal horizontal breadth across the shoulders between lateral margins of the right and left deltoid muscles.
3.Chest Depth	The horizontal distance from the back side to the right nipple.
4.Sitting Height	The vertical distance from the sitting surface to the top of the head, when sitting.
5.Sitting Eye Height	The vertical distance from the sitting surface to the outer corner of the right eye, when sitting.
6.Sitting Shoulder Height	The vertical distance from the sitting surface to the tip of the shoulder.
7.Popliteal Height	The vertical distance from the floor to the underside of the thigh directly behind the right knee; when sitting, with the knee flexed at 90 degrees.
8.Sitting Knee Height	The vertical distance from the floor to the top of the right kneecap, when sitting, with flexed of the knee at 90 degrees.
9.Forearm Hand Length	The distance from the back of the right elbow to the tip of the extended middle finger, with the elbow flexed at 90 degrees.
10.Sitting Elbow Height	The vertical distance from the sitting surface to the highest point on the top of horizontal right thigh, with the knee flexed at 90.
11.Thigh Clearance	The vertical distance from the sitting surface to the highest point on the top of the horizontal right thigh, with the knee flexed at 90 degrees.

12.Head Length	The distance from glabella (between brow ridges) between the most rearward protrusions (the occiput) on the back, in the middle of the skull.
13.Hip Breadth	The maximal horizontal breadth across the hips or thight, whether is greater.

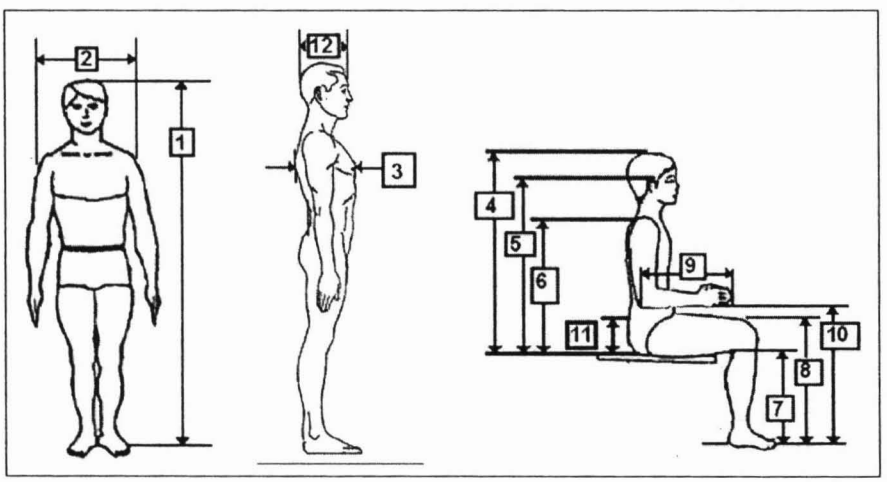
Source: Kroemer et al.,(2008)

Definition of design based on furniture implies the creation of an object that is not only aesthetic pleasing but functionality. According to Jones et al. (2004), when applies to workstation that cannot be adjusted, example like fixed height table, desks or other work surface, designing for the average person better accommodates the entire population. Jones et al. (2004) also stated that when designing whatever products, this situation must be considered. Using limiting dimensions for males and females (5^{th} percentile female and 95th percentile male) it will accommodate approximately 94% of the entire design population (since over 99% of males are larger than the 5th percentile female, and over 99% of females are smaller than the 95th percentile male, so, few small males, or large females, are excluded).

Research Methodology

The data collection sample is conducted at Universiti Teknologi MARA, Kampus Khazanah Alam, Pahang and the sample is among the students in college. The ages range in the samples is around 18 and above years old. These ranges of ages are common for students. The samples involved were 30 male students and 30 female students. Only 60 students are chosen as samples because the purpose of this study is only to compare with the existing data that report from the other researchers before. In order to measure the dimension, 25 minutes were taken to complete this process.

All data is measured by thirteen dimensions of a body part. The thirteen dimensions taken were: stature, shoulder breadth, chest depth, sitting height, sitting eye height, sitting shoulder height, popliteal height, sitting knee height, forearm hand length, sitting elbow height, thigh clearance, head length and hip breadth.



1. Stature
2. Shoulder Breadth
3. Chest Depth
4. Sitting Height
5. Sitting Eye Height
6. Sitting Shoulder Height
7. Popliteal Height
8. Sitting Knee Height
9. Forearm Hand Length
10. Sitting Elbow Height
11. Thigh Clearance
12. Head Length
13. Hip Breadth

Figure 1: Thirteen dimensions on data collection.

Dimension for the existing stool/chair and workbench was measured to determine whether the furniture fit the user or not. The height and width of workbench and stool/chair was be measured. Then, the data was compared with the anthropometric data to produce the better workstation designs.

The tools used to measure the body components were the measuring tape, caliper, long ruler and portable height scale. Then, the data were analyzed by using SPSS for Windows 12.0 and SPC for Excel. Workstations were design by using Computer Aided Design Software.

Results and Discussions

Thirteen anthropometric data were collected among 60 students in the college. Table 4.1 shows the overall data for 60 students including mean, standard deviation, 5th percentile and 95 percentile.

From table 2, mean for sitting height for overall student are 824.05mm, while standard deviation is 42.62mm. The mean stature is 1549.34 and the standard deviation is 212.46. Standard deviation for stature shows the higher value. It means that it have a variation of statue value.

Table 2: Anthropometric data for the males and females college students (all units are in mm)

Dimension (mm)	Mean	SD	5th Percentile	95th Percentile
Stature	1549.34	212.46	1198.78	1899.91
Shoulder Breadh	415.86	50.01	333.35	498.38
Chest Depth	201.79	26.08	158.75	244.83
Sitting Height	824.05	42.62	753.73	894.37
Sitting Eye Height	722.17	28.48	675.18	769.15
Sitting Shoulder Height	557.71	32.72	503.72	611.70
Popliteal Height	427.53	29.75	378.44	476.63
Sitting Knee Height	519.75	29.05	471.82	567.68
Forearm Hand Length	432.19	25.49	390.14	474.24
Sitting Elbow Height	622.68	50.24	539.78	705.58
Thigh Clearance	171.55	28.65	124.29	218.82
Head Length	186.49	19.03	155.08	217.90
Hip Breadth	307.87	25.93	265.09	350.65

Table 3 shows anthropometric data for 30 male and Table 4 shows the anthropometric data for 30 female students including mean, standard deviation, 5th percentile and 95 percentile.

The mean physical characteristics of male and female students are shown in Table 4.2 and 4.3. Male's students show the higher mean value compared to females for stature, sitting height and sitting eye height.

Table 3: Anthropometric data for male college students (all units are in mm)

Dimension (mm)	Mean	SD	5th Percentile	95th Percentile
Stature	1616.56	61.59	1514.93	1718.19
Shoulder Breadh	433.87	64.21	327.93	539.81
Chest Depth	190.47	26.54	146.67	234.26
Sitting Height	863.00	36.05	803.52	922.47

Sitting Eye Height	755.67	28.22	709.11	802.22
Sitting Shoulder Height	587.93	30.98	536.81	639.06
Popliteal Height	439.57	35.28	381.35	497.78
Sitting Knee Height	536.97	32.45	483.42	590.52
Forearm Hand Length	454.70	28.20	408.17	501.23
Sitting Elbow Height	659.53	46.23	583.25	735.82
Thigh Clearance	161.94	33.13	107.28	216.60
Head Length	189.41	20.70	155.26	223.57
Hip Breadth	301.94	29.38	253.47	350.41

Table 4: Anthropometric data for female student's college (all units are in mm)

Dimension (mm)	Mean	SD	5^{th} Percentile	95^{th} Percentile
Stature	1482.13	363.33	882.63	2081.63
Shoulder Breadh	397.86	35.81	338.77	456.95
Chest Depth	213.12	25.62	170.84	255.40
Sitting Height	785.10	49.19	703.94	866.26
Sitting Eye Height	688.67	28.74	641.25	736.08
Sitting Shoulder Height	527.48	34.46	470.63	584.34
Popliteal Height	415.50	24.22	375.53	455.47
Sitting Knee Height	502.53	25.64	460.22	544.84
Forearm Hand Length	409.68	22.77	372.10	447.25
Sitting Elbow Height	585.83	54.25	496.32	675.35
Thigh Clearance	181.17	24.16	141.29	221.04
Head Length	183.57	17.37	154.90	212.23
Hip Breadth	313.80	22.48	276.71	350.89

Figure 2 shows the normal distribution because 90% of the student height lies between 1198.78mm and 1899.91mm (satisfy the requirement of majority of students). Male shows the higher mean compared to female because by nature, male is taller than female. Figure 3 and 4 shows the normal distribution for thight clearance of male and female. It shows that female thigh clearance value is higher than male. Female pelvis bone is wider than men for reproduction purpose (Deros et al., 2009).

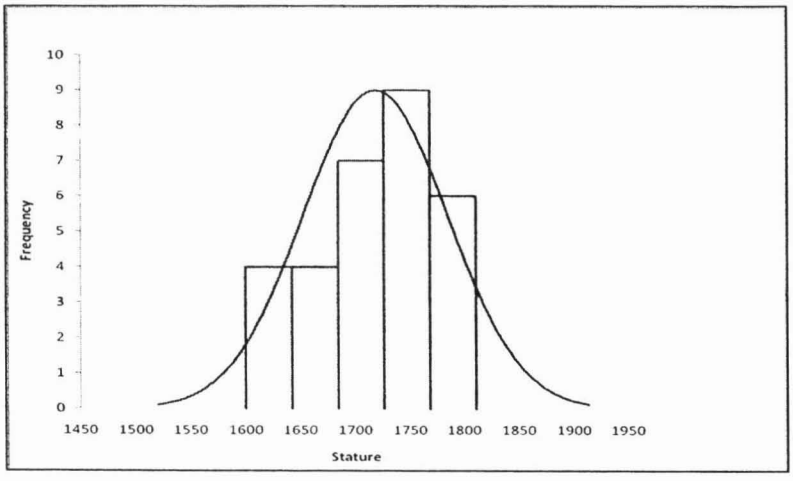


Figure 2: Normal distribution graph for male and female stature

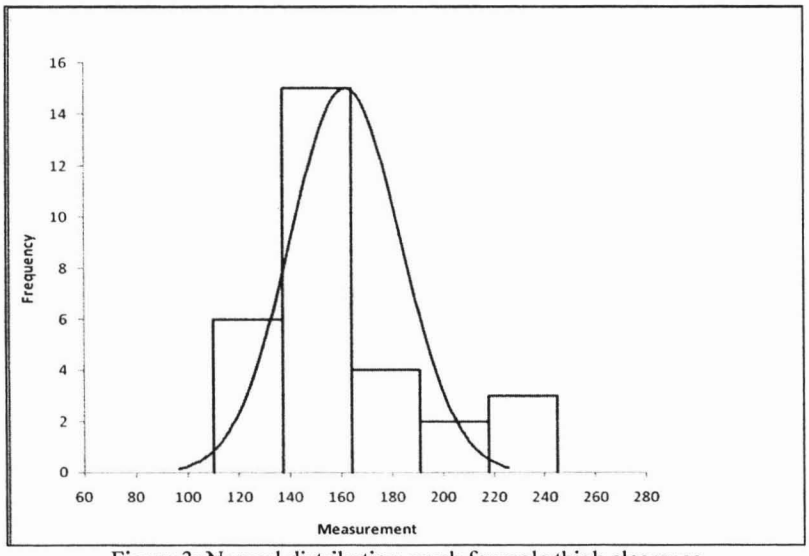


Figure 3: Normal distribution graph for male thigh clearance

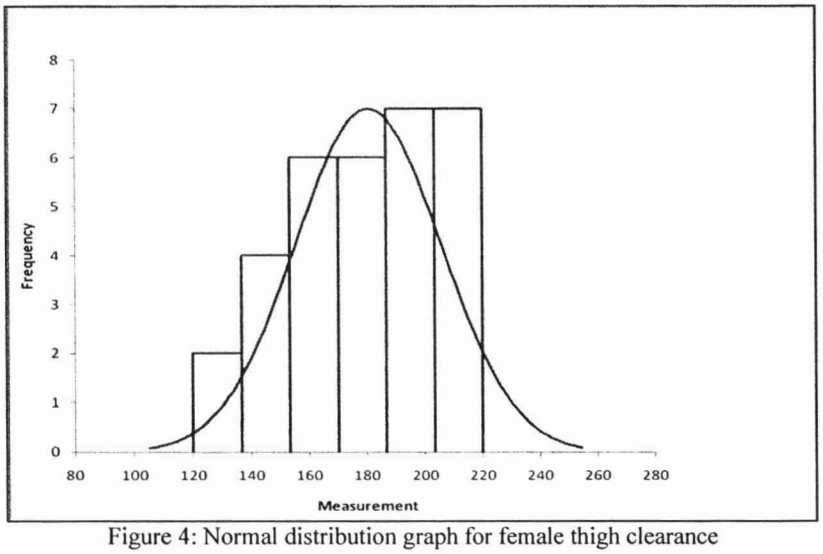


Figure 4: Normal distribution graph for female thigh clearance

Table 2 shows the summary of ANOVA on physical dimension. The purpose is to identify the significant value on physical body dimension. It shows a highly significant ($p<0.01$) between male and female or stature, shoulder breadth, chest depth, sitting height, sitting eyes height, sitting shoulder height, popliteal height, sitting knee height, forearm hand length and sitting elbow height. Significant value ($p<0.05$) shows for thigh clearance and head length. Not significant ($p>0.05$) value for hip breadth.

Table 5: Summary of ANOVA on physical dimension for male and female

Dependent Variable	df	Sig
Stature	1	0.001**
Shoulder Breadth	1	0.009**
Chest depth	1	0.001**
Sitting Height	1	0.000**
Sitting Eyes Height	1	0.000**
Sitting Shoulder Height	1	0.000**
Popliteal Height	1	0.003**

Sitting Knee Height	1	0.000**
Forearm Hand Length	1	0.000**
Sitting Elbow Height	1	0.000**
Thight Clearance	1	0.013*
Head Length	1	0.241*
Hip Breadth	1	0.084n.s

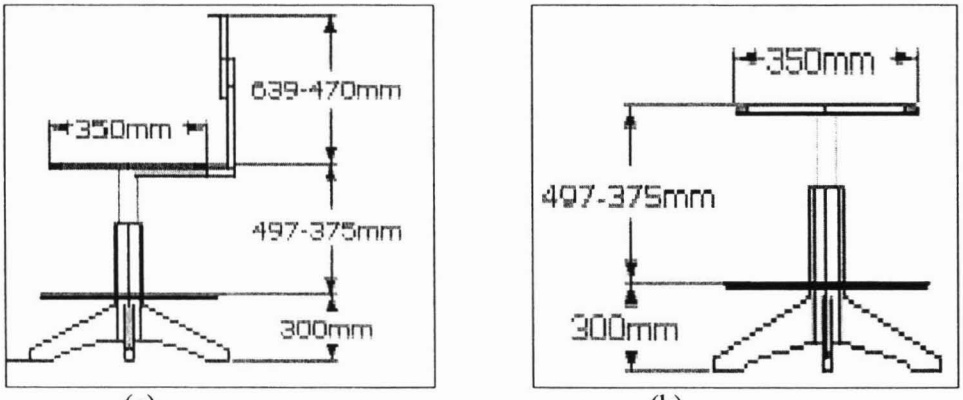
Notes: df: degree of freedom, sig: significant, * significant, **highly significant, ns: not significant

From the data analyzed, this stool is created with the adjustment of the height for the seat from 375 mm to 497 mm above the 300 mm from the ground of the feet support. The adjustment from the 5th percentile of the female popliteal height measurement to the 95th percentile of the male popliteal height measurement from data gathered.

The feet support function is to avoid the leg from hanging above the floor. It also prevents the user from putting extra tension to the lower back muscle. This helps the student to keep the leg comfortable using the stool. From the ground to the feet support to the seat, the height is to make sure the student sit around the hip height to do the task on the laboratory same as when they are standing because lightwork task is comfortable when doing it in the area of hip height to the elbow height.

The stool without the backrest design is less comfortable than the other one but it gives the users more freedom to move the body. It is because the body is not limited to the backrest. The reign of movement is wider than the stool with the backrest.

The backrest for the stool is designed to support the backside of the student when using the stool. The design also support the lumbar reign of the user by the curve shape of the backrest the maximum contact between user back and the stool. The backrest can be adjusted to fit the user back from 639 mm to 470 mm. The measurement is considered from the 95th percentile of male shoulder sitting height to the 5th percentile of female shoulder sitting height.



(a) (b)

Figure 4.10 (a) and (b): Design stool with back rest and without backrest dimension

The table is designed with the height of the average of student elbow height from the ground around 1000 mm and the width of the table is 900 mm. This area is enough for student to do a task and it gives more space to place an apparatus above the table for special tasks. The space below the table to store thing is 350 mm depth enough for student to use. It is from the forearm measurement and the depth is not too deep for student to get their thing inside the storage area.

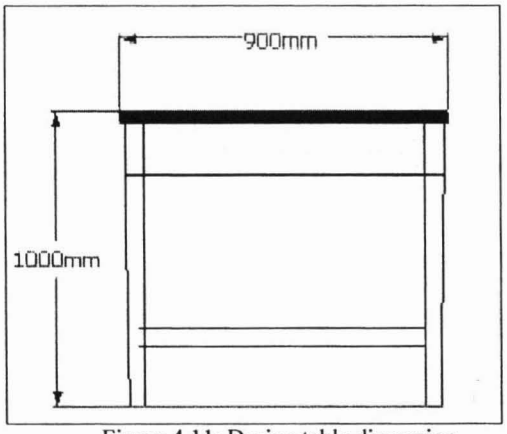


Figure 4.11: Design table dimension

The designs for stool and table are adjusted to be fit to use together in the laboratory. The seats can be with the backrest or without back rest. It is more relaxing when doing a task with the back rest. Other than that, the stool without back rest can be used in the wood working workshop to do the lightwork task such as crafting, hand sanding, screwing, and etc.

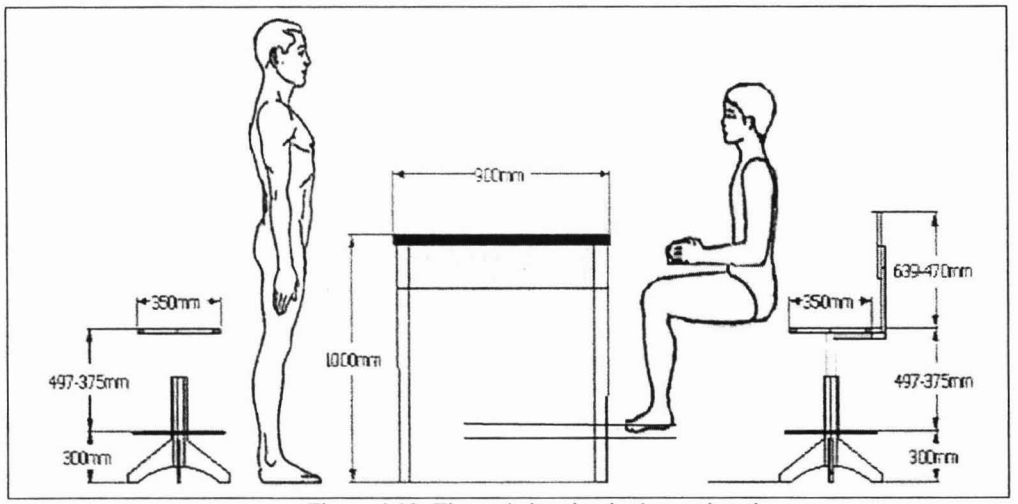


Figure 4.12: The real situation in the workstation

Conclusions

Good design of workstation can be very comfortable for workers in doing their job. It also functions as an important factor to reduce the problem such as fatigue, lack of focus, decrease of studies performance and the main risk is work related musculoskeletal disorder such as lower back pain.

Anthropometric data are very useful to manufactures to produce a comfortable and quality product. Sixty samples of students (30 males and 30 females) were involved in collecting the anthropometric data. Thirteen body dimensions were measured. The data was analyzed. The results show that most of physical dimension are significant between male and female. The comparisons show that mean for physical dimension for male is higher than female. This data also compared to the existing data from Deros et al. (2009). The data also give the same trend/result that mean physical dimension for female smaller than mean for male.

A new design were proposed based on thight clearance, hip breadth, sitting shoulder height, popliteal height and standing elbow height (Siringoringo et al., 2008). The suggestion for new workstation is combination of

stool that can be adjusted and workbench are fixed. For stool that can be adjusted, it was considered from the 95th percentile of male and the 5th percentile of female. Fixed item is used on overall male and female data.

Existing workstation and proposed workstation was compared. It shows that the differences height between existing workbench and new design workbench are small. It can say that, the current and new design of workbench suit the mean of physical dimension. It is strongly agreed that current workbench and new design workbench was satisfied for user if they do the job by standing position.

A stool was compared in sitting position. It is clearly seen that existing stool is not compatible with the student's dimension. It is because of the combination of fixed stool and fixed workbench. For achieving the 90 percent satisfaction of laboratory user, combination of adjustable stool and fixed workbench was designed. In reality, many researchers reported on the findings. Mandel (1994) stated that adjustable workstation is very suitable both for small and large users to fell comfortably and easily to reach the things.

It is recommended that measured body dimension process must be done in close room to give some privacy to the subjects. When doing the data anthropometric collection process, use the scientific tool to get an accurate data.

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