Creative Ergonomics Solutions

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Abstract - **Many safety officers in Thailand face the difficulty to improve their ergonomics workstation, since they lack the knowledge of ergonomics design and a medium to communicate their ideas. They also do not know how to redesign their workstation and create a better solution. The aim of this research is to create an Ergonomics Prototyping Framework with a method to deliver the design in conjunction with paper prototyping technique. Computer workstation on both desktop and notebook is an example of the case study. Thirty subjects who are mainly safety officers participated in the Safety Week workshop. The process includes the lecture and practice on the ergonomics knowledge, ergonomics assessment, anthropometric design and paper prototyping. The result shows that subjects gain the higher level of knowledge and skill significantly. They also perceive the value of the paper prototyping and were satisfied of the workshop results. Five ergonomics experts are pleased the workshop outcome.**

Keywords – **Paper Prototyping, computer workstation, ergonomics design**

I. INTRODUCTION

Ergonomics problems in Thailand are often found in plant and office workstation. For example, some of the manufacturing machines imported from aboard do not fit in Thai workers scale. Many workstations like office desks and chairs ordered by purchasing department are the same average size while users have different body sizes. Also, Thai manufacturers do not design the size of furniture that fits Thai populations. As seen in workplaces, many of female office workers customize their seats by inserting their cushions behind their backs. As a result, workstations either imported from aboard or designed in the country need to be improved.

Ergonomics curriculum in Thailand is quite severe due to the council of engineers has changed compulsory course regarding ergonomics into elective one since 2004. This is a problem for Thai engineers have not used the knowledge of ergonomics to improve their workplaces. A lot of safety officers know the topics in ergonomics but never practice how to design and solve the problem of workstation. Many safety officers who have graduated from the faculty of public health meet the difficulty on how to improve their workplaces ergonomically. As a result, the method and medium that guide safety officers to improve their workstations can be a driving force for ergonomics solution. In this study, the paper prototyping technique is proposed as a medium for safety officers to create their own design. To make the paper prototyping more effective, the framework needs to be established.

Prototypes as tools for traversing a design space where all possible design alternatives and their rationales can be explored [1]. Designers communicate the rationales of their design decisions through prototypes. Prototypes stimulate reflections, and designers use them to frame, refine, and discover possibilities in a design space. The use of low-fidelity prototypes in industry is widespread because they offer a number of advantages, such as rapid availability and low development cost [2]. The classic example of low-fidelity prototyping is the paper prototyping using pen and pencil to mockup interface screen. Currently, the paper prototyping benefits to the software community, and it should be applied for the ergonomic community. Since the paper prototyping cannot function well with the physical properties, the materials of the prototyping are modified to fit the ergonomics aspects. The main material used for the paper prototyping is a card board that can be designed as a rigid structure. Using the paper prototyping reduces the risk of investment on the final product. Therefore, it is possible to create prototypes as many as possible.

The aim of this research is to create a framework that can assist the practitioners to create a design output by using the paper prototyping. The method should inspire the creativity, solve the design problem and visualize the potential idea.

1) Ergonomics Prototyping Framework

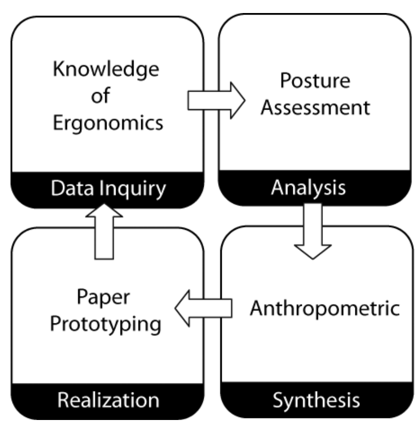

Fig. 1. Ergonomics Prototyping Framework

Table I

APPLICATION OF ERGONOMICS PROTOTYPING FRAMEWORK

	Computer workstation	Industrial workbench	Hand tool
Know-ledge of Ergono-mics	1. Ergonomics problem of computer workstation and working posture 2. Desktop and notebook computer 3. Risk – Musculoskeletal disorders, Repetitive Strain Injury, Eyestrain, and Carpal Tunnel Syndrome 4. New design workstation	1. Ergonomics problem of industrial workbench and working posture 2. Stand/Sit 3. Risk – Musculoskeletal disorders, Frozen shoulder, Carpal Tunnel Syndrome, Severely aching feet, and Malformations of toes	1. Ergonomics problem and awkward posture 2. Biomechanics - Force, grapping and gripping strength 3. Risk – Ulnar nerve entrapment, Trigger finger, Tenosvnovitis, and, Tendonitis
Posture assess-ment	1. Rapid Upper Limb Assessment (RULA) [3] for computer user on upper arm, lower arm, wrist, neck, trunk, legs, muscle use, and load. or 2. RULA for computer [6] 3. Body discomfort [7]	1. Rapid Entire Body Assessment (REBA) [4] 2. Body discomfort [7]	1. Non-power hand tool [5] 2. Body discomfort [7]
Anthro-pometric	1. Measuring body Sitting posture – chest depth, shoulder grip length 2. Measuring furniture 3. Measuring space – i.e., reach distance, kick room, knee room	1. Measuring body Sitting or standing posture 2. Measuring workbench 3. Measuring space – i.e., reach distance, feet room	1. Measuring the arm part - palm breath, hand length, hand circumstance 2. Measuring the hand tool 3. Measuring the force – i.e., load cells
Prototypi ng	Material – cardboard, adhesive tape Structure – rib, joint, add-on and truss design	Material – card board, adhesive tape Structure – rib, joint, add-on and truss design	Material – clay, plastic Structure – contour design

Four phases of the framework start from giving the knowledge of ergonomics to participants. This is a fundamental knowledge that includes the problem of existing products and possibility of new design. The second phase is the posture assessment. There are several methods used in this phase such as RULA [3], REBA [4] and Hand tool assessment [5]. These posture analysis methods are easy for practitioners to use. They can analyze the problem without having sophisticated knowledge or special tools. The third phase is to use the anthropometric design to measure a human body and workstation. Then they can design a workstation based on the dimensions that they have got from measurement. This process is not only a data collection but also a synthesized idea by using the dimension. For example, the size difference between human body and workstation could be used to design an appropriate dimension for new design. The final phase is paper prototyping. This technique is used to visualize the design and make it more realistic. The prototyping could be used as a tool for users to deal with the configuration of workstation. For example, they can cut and fold the paper of workstation that fits the human dimensions.

2) Application of Framework

Table I presents an application of the framework that can be applied for different working conditions such as computer workstation, industrial workbench and hand tool. While the working conditions are different, the teaching and material that are used for each phase of framework are not the same. Computer workstation and industrial workbench are put close together to each other, since they share the same assessment such as sit posture. In contrast, the hand tool focuses more on the action force on the tool. This property relates to the knowledge in Biomechanics. As a result, the materials for the prototyping are plastic and clay instead of the card board that cannot resist the hand pressure.

II. METHODOLOGY

The desktop and computer workstations were selected as a case study since both used the same principle of ergonomics knowledge and assessment. The workshop was conducted at the national Safety Week on July 10, 2010 in Bangkok. The workshop was hosted by Ergonomics Society of Thailand (EST). In the morning session, there were around 100 participants joining the activities. Due to limitation of the material and human resources, the EST set only 30 participants, 10 males and 20 females, for the workshop in the afternoon session. 17 of them were safety officers whereas the rest were from other departments such as office workers. The age ranged from 23 to 57; the average was 36. There were two parts of the workshop: one lecture and one practice. After the subjects finished the workshop, the questionnaires were given to the participants and experts. Subjects were divided into two cases within eight groups. The odd numbers were for the notebook while the even numbers were for the desktop.

Process of the workshop

1. Lecture on the fundamental ergonomics including the problem and existing computer and notebook workstation (40 mins. – see Fig. 2a)
2. Lecture on the posture assessment (40 mins.)
3. Lecture on anthropometric (40 mins.).
4. Lecture on the paper prototyping (40 mins.)
5. Question and Answers Session (10 mins.)
6. Give a brief of workshops – desktop workstation and notebook workstation
7. Select one subject to be a model for assessment and measurement (see Fig. 2b)

8. Simulate the task by asking the model to sit and use the existing workstation
9. Use ergonomic assessment for analysis and identifying the problem
10. Measure the human scale and the workstation by filling in the form [8] by comparing the dimension between human scale and workstation. Participants can use this dimension for designing a workstation and solve the problem.
11. Design by sketching on paper or make a three dimensional model (see Fig.2C)

Fig. 2: Ergonomics workshop during Safety Week

Instruments

1. Ergonomics assessment – RULA for computer and anthropometric form (see Appendix for details).
2. Paper cardboard size 1 x 1.5 meters by 3 layers and 5 layers.
3. Paper copy of notebook, keyboard and display layout. The size of monitor is 15" and the size of keyboard is 17 x 45 cm.
4. Roll-up and plastic tape measures.
5. Stationery such as adhesive tapes, cutters, and metal rulers.

III. RESULTS

The results of the workshop are from three parts to validate our method. The first part is the result of design output created by participants. This result was evaluated by using the regular ergonomics assessment such as RULA. The second result is based on the questionnaire from the participants evaluating the knowledge and skills before and after participating in the workshop. The third result is from the experts' review by using the rating scale. The experts evaluated the design of the paper prototyping.

A. *Results of design output*

Fig 3. The paper prototype of notebook and desktop

When RULA is used for computer to evaluate the output from the eight teams in the workshop (see Fig. 3), it is clear that there are two identical parts. Scores A and B are a cumulative value of Tables A and B in the RULA form (see Table II referred to Appendix Fig.A1). The desktop has a higher score on upper part (Score C) and lower parts of the body (Score D) than the notebook does. The outcome of the assessment shows that the desktop groups belong to the action numbers 2 and 3, which are acceptable. The desktop belongs to action numbers 3 and 4, that requires further investigation and changes. The reason why notebook has more problems in ergonomics is that the display cannot be separated from keyboard. It is difficult to do the separated adjustment.

TABLE II
Evaluation of outcome using the RULA for computer

Group number	Upper arm	Lower arm	Wrist	Score A	Neck	Trunk	Legs	Score B	Score C	Score D	Grand total
1	2	1	2	*3*	2	1	1	*2*	*4*	*3*	**3**
3	2	1	1	*2*	2	1	1	*2*	*3*	*3*	**3**
5	2	2	2	*3*	2	1	1	*2*	*4*	*3*	**3**
7	2	1	1	*2*	3	2	1	*3*	*3*	*4*	**4**
2	1	1	1	*1*	1	1	1	*1*	*2*	*2*	**2**
4	1	1	2	*2*	1	1	1	*1*	*3*	*2*	**3**
6	1	1	1	*1*	1	1	1	*1*	*2*	*2*	**3**
8	2	1	1	*2*	1	1	1	*1*	*3*	*2*	**3**

A1. Display monitor

The reason of more risk in notebook workstation is about the level of display and keyboard. Two techniques were used to level up the height of display. Group 1 leveled up the display by putting additional legs for the notebook. Groups 3, 5, and 7 used the stand to make the display higher. All notebook groups did not have enough height of display which could cause the neck pain. For the desktop, the height of monitor was better than that of the notebook. Many of the group proposed the adjustable height such as Groups 2, 4 and 6. On the other hand, Group 8 adjusted the length between head and display.

A2.
Keyboard

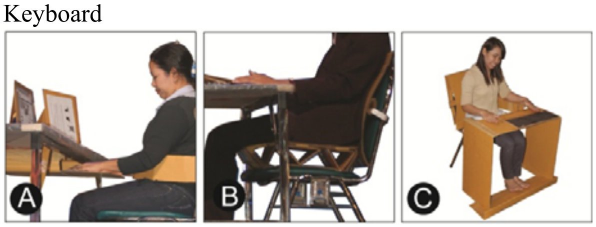

Fig. 4: Design to support the upper arm, lower arm and wrist

All notebook groups placed the keyboard on the table except the group 3 (see Fig. 4a). As a result, many groups had a risk on upper arm and wrist. Group 3 designed a keyboard tray below the table, so they required additional keyboard. Group 7 solved the problem of upper arm and wrist by leveling up the seat instead (see Fig. 4b). For the notebook workstation, Groups 2, 4, and 6 created a tray of keyboard below the table. Group 8 designed an interesting tube structure (30x70x60 cm.) to hold the keyboard and the foot rest (see Fig. 4c). Additional designs that supported the lower arm could be seen in the group of desktop. Groups 4, 6 and 8 designed the arm support that could adjust to the front and back.

A3. Seat

All groups designed a curve of back seat to support the s-curve lumbar. Group 3 missed the design of lumbar support. Another interesting part was to design a cushion. Groups 1, 5, 6 and 8 designed a cushion to increase the height and extend the seat depth. Group 7 leveled up the seat around 10 cm. since the model was small. This group used the structure of truss to build the cushion.

A4. Foot rest

The groups 1, 2, 3, 4, 7 and 8 had foot rests. Many of them were inclined around 15° degree. Some groups gave support to the foot rest because the model was small.

B. Results of participants

Thirty participants responded to the post-questionnaire after the workshop as seen in Table III. The questionnaire is 5-point Likert scale. On scale, '1' corresponds to the least and '5' correspond to the most. Q1 to Q3 are knowledge of ergonomics. Q4 is an ergonomics assessment. Q5 to Q8 are the anthropometry part. Q9 to Q11 are about paper prototyping. They were asked to compare between pre and post training. The result shows that there is a significant difference from the question 1 to 11($p < 0.001$). The most significant difference is the question numbers 9, 6, 5 and 8 respectively. Those questions relate to the prototyping of card board, and anthropometric of human and workstation. It could be assumed that many subjects did not have an experience of improving their workstations before. For the Q12 (How do you satisfy your prototype?), the mean is 3.82 of 5 points (SD = 0.61). It means that participants are satisfied of the prototype that they have made. The Q13 (How do you apply this workshop to your workplace?) mean is 4.07 (SD = 0.66). It represents that most of the participants believe that they can apply the knowledge to their works much.

C. Expert Reviews

Five experts with experience of occupational ergonomics for more than 5 years rated all eight groups by using the 5 point Likert scale as follows: Q1) Does the prototype prevent the injury?, Q2) Does the participant design creatively?, Q3) Does the dimension of prototype fit the user?, Q4) Does the prototype reflect the usage?, Q5) How do you satisfy their prototypes?, and Q6) How much do the participants apply this workshop to their works?

Q1 shows how the participants solved the problem of computer workstation. The average highest scores of desktop and notebook computer are group 8 ($\mu = 4.2$) and

7 (μ = 3.6) respectively (Fig. 5). Group 8 solved the problem by separating the keyboard from the desk while the seat cushion was designed to increase the height of the model. For creativity (Q2), group 8 has the highest score (μ = 4.8) in desktop computer side, while group 3 has the

TABLE III
Paired sample T-test from pre and post workshop

			Mean	Std. Deviation	t - value	Sig. (2-tailed)
Pair 1	How much do you know about the problem of existing workstation?	Q1 pre	3.1	1.02	5.29	0.00
		Q1 post	4.07	1.08		
Pair 2	How much do you know about any injury while working on the workstation?	Q2 pre	3.07	0.86	8.72	0.00
		Q2 post	4.3	0.46		
Pair 3	How much do you know about any workstation in the market that uses the ergonomics principle?	Q3 pre	2.87	0.86	7.50	0.00
		Q3 post	3.97	0.61		
Pair 4	How much do you know about the risk from the awkward working condition?	Q4 pre	3.5	0.68	6.53	0.00
		Q4 post	4.33	0.60		
Pair 5	How much do you know where to measure in the human body for designing the workstation?	Q5 pre	2.87	0.86	9.63	0.00
		Q5 post	4.2	0.66		
Pair 6	How much do you know where to measure in the workstation for designing the workstation?	Q6 pre	2.83	0.95	9.78	0.00
		Q6 post	4.2	0.71		
Pair 7	How much do you know the reach distance?	Q7 pre	2.73	0.98	7.99	0.00
		Q7 post	3.87	1.00		
Pair 8	How much do you know about the space between users and workstation?	Q8 pre	2.63	0.99	9.63	0.00
		Q8 post	3.97	0.99		
Pair 9	Do you know how to make the workstation by using the card board?	Q9 pre	2.3	0.87	10.8	0.00
		Q9 post	3.83	0.95		
Pair 10	Do you know how to adjust your prototype to fit the dimension of users?	Q10 pre	2.7	0.95	8.65	0.00
		Q10 post	4.03	0.89		
Pair 11	Do you know how to demonstrate your prototyping?	Q11 pre	2.73	1.01	7.41	0.00
		Q11 post	3.93	0.98		

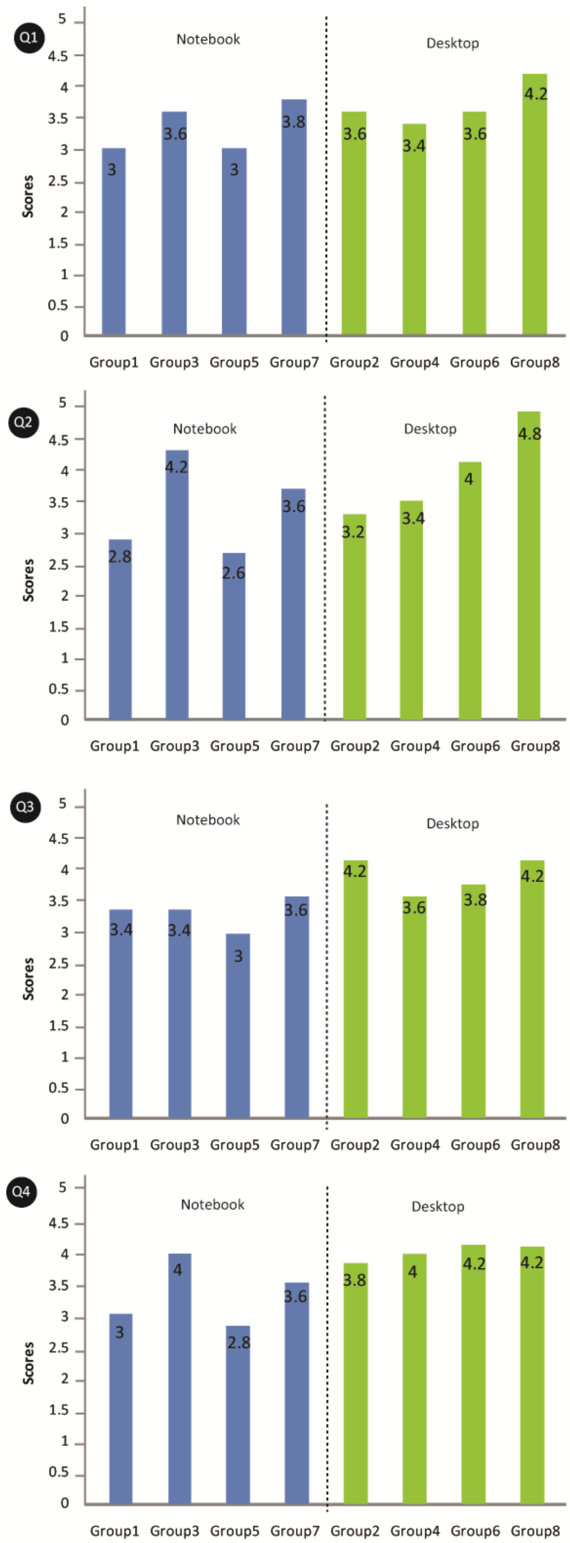

Fig. 5. Experts' evaluation

highest score (μ= 4.2) in notebook side. Group 3 preferred designing a separating keyboard tray to using the keyboard on notebook like other groups while group 8 designed a separate cube for keyboard and footrest. For the Q3, group 2 and 8 have the same highest score (μ=4.2) in notebook slide. Group 3, 5 and 7 have similar scores for keyboard and footrest. Groups 2 and 8 have a proper design of the size and distance from the monitor display. For the function of prototype in Q4, the desktop computer has many highest score like Group 8(μ=4.2), 6 (μ= 4.2) and 4 (μ= 4). Group 3 has the highest score in notebook side (μ = 4). For the satisfaction of the outcome in Q5, experts rated all groups ranging from 3.2 to 4.2. This shows that all experts are satisfied of the outcome of the workshop. As same as in question Q5, experts rated all group ranging from 3.2 to 4.4.

IV. DISCUSSION

The Ergonomics Prototyping Framework illustrates how to use the prototyping as a medium effectively. Due to the limited workshop time within 6 hours, the outcomes of the prototyping from many groups are not much different. Giving more time could generate more creative ideas. Before starting the workshop, many subjects expected that the prototyping would be difficult to do. After they learned by doing, the prototyping challenged their ideas and problem solving skills. The method has been used 6 times for 2 years with different kinds of occupations such as engineers and interior designers. The result shows that creativity could jump from the traditional way of thinking by changing case studies or types of workstation. Instead of using the regular chair for the notebook, the lecture chair could be one for making the product more creative (see Fig. 6a, 6b, 6f and 6g). This prototype helps users hold the notebook and prevent the notebook to fall (Fig. 6b). Moreover, the design of paper could support the heat ventilation and level up the notebook (Fig. 6a). For the case like industrial workbench, a new design of task can make the prototyping a more creative tool such as a subject designed as a cone for inserting a coin precisely (Fig. 6c). Another group designed a sit and stand chair that works with the task of arranging boxes (Fig. 6d). Figure 6e shows a notebook computer workstation in practice.

V. CONCLUSION

The results from RULA assessment show that there are still some risks in ergonomics but the creative problem solving is evidently shown in the workshop. The workshop can turn the knowledge of ergonomics into practices as seen in the difference between pre-post questionnaires. Experts also rated the outcome above average. The contribution of Ergonomics Prototyping Framework and method can allow practitioners to improve or design a new workstation without any barriers of making skill.

Fig. 6. Other Creative Ergonomics Solution Workshop

ACKNOWLEDGMENT

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APPENDIX

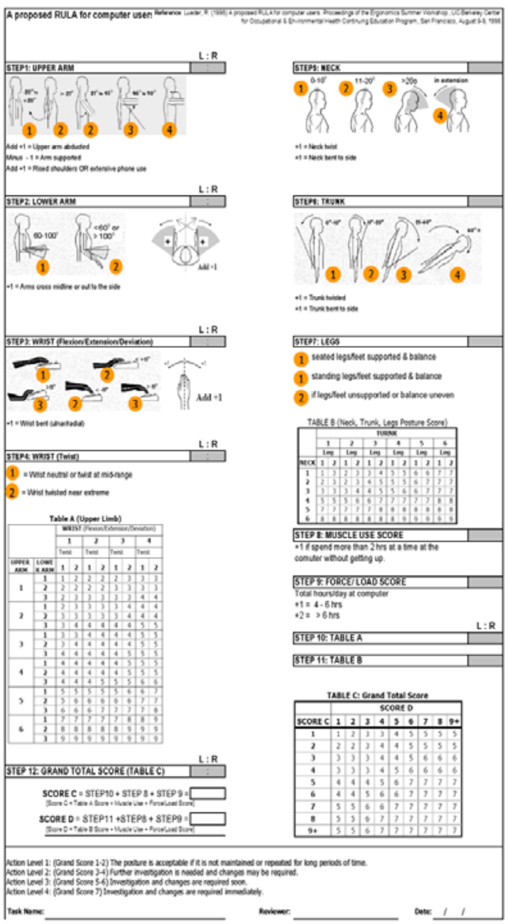

Fig. A1. RULA for Computer [6]

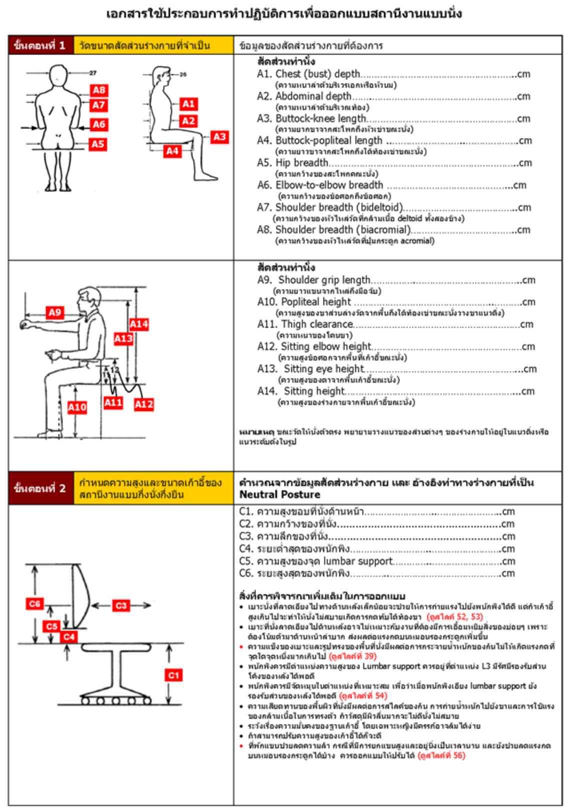

Fig. A2. Anthropometric of man and workstation [8]

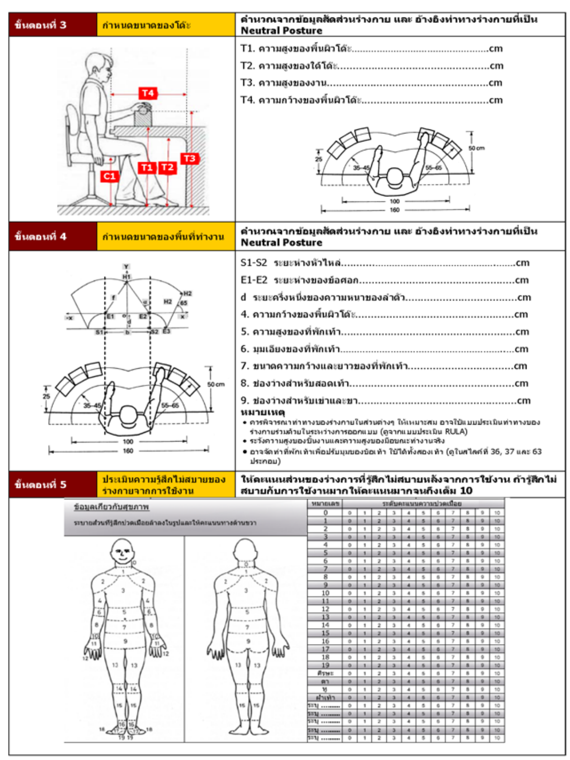

Fig. A3. Anthropometric and Body discomfort [8]