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DESIGN AND ERGONOMICS ANALYSIS OF WORKSTATION FOR ONLINE LEARNING DURING MOVEMENT CONTROL ORDER

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ABSTRACT

This paper discusses workstation design based on ergonomics using Rapid Upper Limb Assessment (RULA). The workstation was designed and the RULA was performed using CATIA software. This study focuses on personal experience when using the chair and desk during online learning, studies, conducting assignments, and reports, therefore, the initial data was derived from this experience then the data was analyzed using RULA to achieve a better score with an acceptable level of Musculoskeletal-Disorder risks. Then, only the chair was optimized to obtain a final score of 1 (best posture) from a score of 3.

Keywords: ergonomics, posture, rapid upper limb assessment (RULA).

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INTRODUCTION

Universiti Teknikal Malaysia Melaka (UTeM) resorted to online learning from the 4th of May 2020 in compliance with social distancing and the Movement Control Order (MCO) implemented by the Malaysian government on the 18th of March 2020 as a preventative measure to fight Covid-19. All students from Universiti Teknikal Malaysia Melaka were conducting their studies online both at the undergraduate and postgraduate levels. Therefore, with the implemented measures, more time is spent indoors while seated on a chair and desk (workstation) to access online lectures, study, and complete assignments or projects.

Figure-1 shows the existing workstation that is being used to conduct online lectures, studies, and complete assignments. Based on personal experience because of the current scenario, normal body stresses are felt around shoulders, arms, neck, wrist, and low back pain because the workstation in my room is not suitable for long time usage.

Figure-1. Existing workstation.

There are times/days when some work is done while seated on the bed so that you give yourself time to recuperate from the Musculoskeletal Disorders (MSD) developed on the workstation. The chair currently in use does not have proper lumbar back support, armrest, and no adjustable mechanisms while the desk does not have a footrest. These problems call for an improved workstation design in terms of ergonomics to provide comfort to the user for a longer period with a low level of injury risk.

The objectives of this project are:

a) To evaluate the current workstation (chair and desk) design in terms of ergonomics using Rapid Upper Limb Assessment (RULA) to obtain a score that will indicate the level of injury.
b) To design a workstation with ergonomic aspects, based on the results from the first objective to reduce the level of Musculoskeletal Disorder risks -MSD risk to a score of (1-2).

LITERATURE REVIEW

This literature review discusses RULA and the most important features of a chair and table, to give an insight into the factors to be put into consideration when designing an ergonomic workstation. The RULA method was developed by Dr. Lynn McAtamney and Professor E. Nigel Corlett, ergonomists from the University of Nottingham in England. RULA is a postural targeting method used to estimate the level of work-related upper limb disorder risks. RULA provides a quick and systematic assessment of the postural risks to a worker. RULA has a range of final scores of 1 to 7. The scores are divided into 4 levels that are; 1-2, 3-4, 5-6, and 7+. A score of 1-2 shows that the person is working in the best posture with no risk of injury from their work posture while the other scores show a risk of injury from the work postures requiring an associated action to mitigate the risks depending on the level of risk. The RULA can be

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done before and after an intervention to demonstrate that the intervention has worked to lower the risk of injury (Mat *et al*, 2017).

With the rising models of products, people's choices and product taste are changing very rapidly hence products are being modified constantly to satisfy the user or customer. Ergonomics and human factors are significant considerations when it comes to product design, Lin *et al*., (2004) said that for the past 30 years ergonomic chair design has emerged as a very important concern. Pope *et al.*, (2002) stated that prolonged seating, fixed postures, and awkward postures are also some of the risk factors that increase pressure on the human body causing Musculoskeletal Disorders (MSD). Work-related Musculoskeletal Disorders (MSD) may affect shoulders, arms, elbows, wrists, hands, back, legs, and feet (Yusop *et. al,* 2018). The posture of a person seating on a chair does not depend only on the chair design but on tasks being performed and sitting habits in an attempt to find a better seating position (Al-Hinai *et al.,* 2018). Height, chair seat inclination, backrest, armrest, and other types of support play a part in the resulting posture. Lumbar spine support reduces spine deformation and the associated low back pain. Work-related Musculoskeletal Disorders (MSD) symptoms include tenderness, aches, pains, tingling, stiffness, swelling, and lower and upper back pain.

According to Zakaria (2015), a chair has to be adjustable for height and backrest whereas the internal lumbar support should also be adjustable relative to the user. A chair is considered ergonomic when it specifically suits the user and the related tasks being performed. Figure-2 below shows the main seat dimensions.

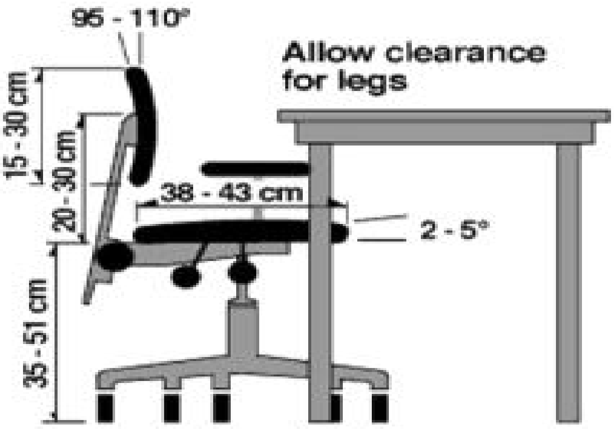

Figure-2. Major seat dimension (Canadian Centre of Occupational Health and Safety, 2020).

Haworth (2008) stated that a chair with a fixed seat pan length limits the number of users who can fit into the chair where a taller person requires more seats pan length while a shorter person requires less. A shorter person will feel pressure behind the knees when sitting on a long pan whereas a taller person will have inadequate support when sitting on a short pan length hence there will be high contact pressure under the thighs. Then the paper recommended that for good ergonomics, the seat should incorporate adjustability to the seat depth of 2 to 3 inches. McKeown (2008) indicated that office chairs provide a wide range of adjustments but vary from one model to another. This paper recommended that a seat should be able to provide adjustability from 380mm to 530mm above the floor to the seat.

The backrest of chairs is now sophisticated and in various forms. Before making any style decision on the backrest, the pros, and cons should be considered for each design (McKeown, 2008). The backrest should be designed in such a way that the lumbar support fits properly with the lower section of the back. The backrest material should be capable of being adjusted to mold around the user depending on the design and it should be capable of tilting.

McKeown (2008) argued that it is not true that having an armrest on a chair will prevent the user from developing upper limb disorder because poorly designed and positioned armrests can create problems for the user. For example, some armrests can prevent a user from sitting close to the leading edge of a desk hence there will be a greater distance for a user to reach a keyboard, mouse, etc. when working on a desk and the user will be forced to extend their arms forward hence losing the armrest support. Sometimes to avoid this problem, users will lower their seats so that the armrest should be under the desk for the user to pull closer to the desk, but this only creates new problems because now the height to the level of the mouse and keyboard will be different to the user seating positing, forcing the user to raise the shoulders while working and this will result into fatigue and discomfort. Today, the armrest is capable to be adjusted in various ways, but the writer recommended that if the armrest provides discomfort to the user then it should be removed from the chair.

Kroemer (2001) defined comfort as 'a pleasant feeling of being relaxed and free from pain'. This paper also recognized seat comfortability is determined subjectively but further outlined that a seat surface should be capable of being adjusted (decline forward to inline backward) to allow the user to assume different curvatures of the lower spinal column. The seat surface should support the weight of the upper body comfortably. Proper upholstery, cushion, and other elastic or materials that can adjust plastically to body contours were recommended, unlike the hard surfaces that generate pressure points. Kroemer (2001) highlighted that the backrest should be as large as possible if it can be accommodated by 85cm above the seat pan and by 30cm up the region. Should be shaped to align with the back contour. An adjustable pad or inflatable cushion is recommended to support the lumbar lordosis. The lumbar pad should be adjustable from 12 to 22cm; the cervical pad should be adjustable from 50 cm to 70 cm above the seat surface.

Armrest provides support for the weight of arms and hands. Kroemer (2001) recommended that adjustability in height, width, and direction is desirable for the armrest but he also recognized that the armrest could hinder the user when moving the arm, pulling the seat

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closer to the desk, or when getting in and out of the seat. The study suggested that having shorter armrests or none is recommended.

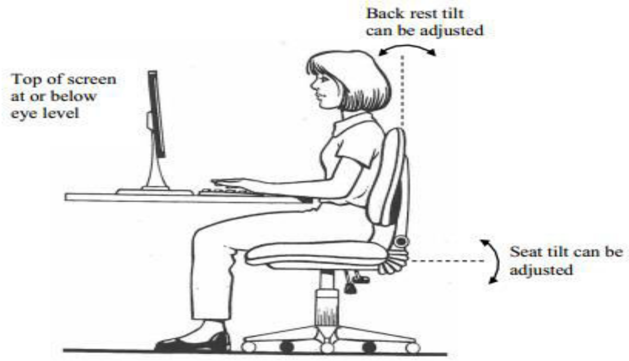

Figure-3. Acceptable sitting position (The State of Queensland, 2012).

The State of Queensland (2012) discussed that a desk or workstation should have adequate height, depth, and work surface suiting the user and the related tasks being performed. The paper recommended that a workstation should have a flat smooth surface, 680-720mm height measured from the top of the desk to the floor, and be spacious for leg stretches. The paper discussed that height-adjustable workstations are more desirable, especially for users who are very tall or short so that they can adjust the workstation to suit their sizes. Figure-4 shows scalloped desks as compared with straight-edge desks. The scalloped desktop provides several advantages: more opportunity for forearm support, greater desktop space within acceptable reach zones, and better work postures when using multiple screens.

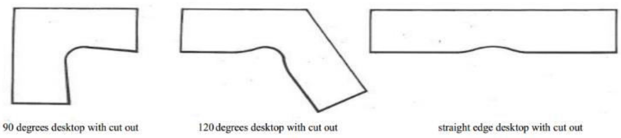

Figure-4. Scalloped desks (The State of Queensland, 2012).

The paper also discussed that a footrest should only be used when the user's feet can not be placed flat on the floor. The footrest should have a 30 × 30 cm non-slip surface, a 10-20 degrees adjustable slope, and should be stable so that it does not slide.

METHODOLOGY

Morphology Chart

A morphological chart is a technique that helps to generate concepts for the product to be created from various ideas. It is compared in a table based on the analysis of the components. By using this method, a potential design can be identified. This chart was developed to generate a single system from a different mechanism. In other words, a morphological chart is an early stage in generating the concept design of the product. The morphological chart for the chair is shown in Table-1. The morphological chart for the chair was constructed by screening all the chairs in the markets. Some of the designs of the components in the morphological chart are improvised from the chairs from the markets.

It should be mentioned that the existing desk/table will not be modified in terms of its original dimensions and it will be used with the chair during the RULA for the existing workstation and proposed workstation.

Table-1. Morphological chart for chair design.

Component	Design 1	Design 2	Design 3	Design 4
Seat	SQUARE 	ROUND 	BENT RECTANGULA 	IRREGULAR 
Leg				
Back rest				
Arm rest				

Conceptual Design

Concept 1: Existing Workstation

The chair, desk, and Laptop were designed and assembled, and the dimensions used are the same as the current workstation that is being used. This concept has been developed so that the current workstation can be analysed in CATIA software using RULA to assess the level of Musculoskeletal Disorder risks that author facing, then depending on the RULA score, modifications can be made to reduce the risks to an acceptable level. Figure-5 shows the existing workstation developed.

ADVANTAGES

a) The chair is cheap
b) No armrest to restrict movements, in and out of the chair

DISADVANTAGES

a) No comfort, the seat pan, and backrest are hard
b) The design does not influence the user's good posture.

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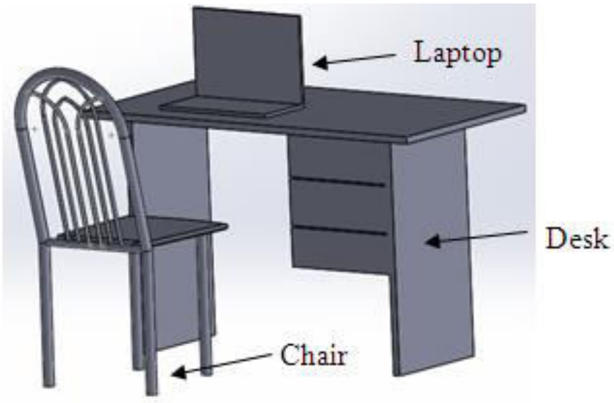

Figure-5. Existing workstation (Concept 1).

Concept 2: Adjustable chair with fixed armrest

The chair dimensions have been done based on the author's body anthropometric measurements. Figure-6 shows the Concept 2 design.

ADVANTAGES

a) The chair can be adjusted to suit the user
b) Backrest and seat pan are made from soft cushions for comfort to the user
c) Armrest for support during prolonged seating

DISADVANTAGES

a) Armrest may limit user movements in and out of the seat.

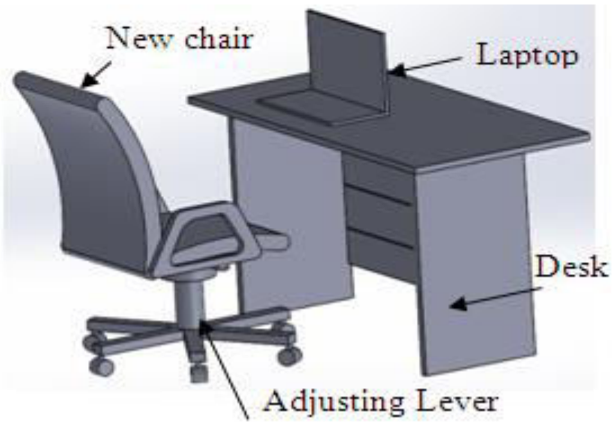

Figure-6. Adjustable chair with fixed armrest (Concept 2).

Concept 3: Adjustable chair with adjustable armrest

Figure-7 shows the Concept 3 design.

ADVANTAGES

a) Backrest, headrest, height, seat pan, and armrest can be adjusted to suit the user
b) Backrest and seat pan are made from soft cushions to provide comfort to the user
c) Seat pan, backrest, and headrest follow the user contour.

DISADVANTAGES

a) It has a lot of parts

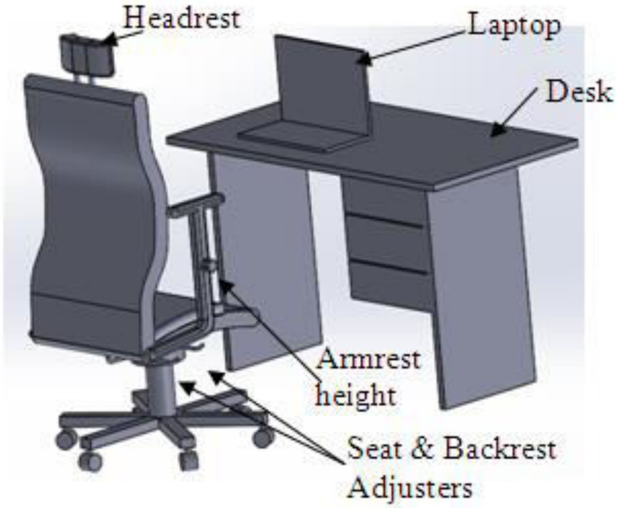

Figure-7. Adjustable chair with adjustable armrest (Concept 3).

Selection of Conceptual Design and Detail Design

This project has three concepts, one concept is the existing workstation and the other two concepts have been generated using the morphological chart. When a small number of concepts are generated, the concept screening process can be omitted, instead, concept scoring can be done directly. Table-2 shows the concept scoring matrix.

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Table-2. Concept scoring evaluation matrix (Salima *et al*., 2020).

Concept scoring Evaluation Matrix							
		CONCEPT 1: exisitng workstation		**CONCEPT 2: Adjustable seat with fixed armrest**		**CONCEPT 3: Adjustable seat with adjustable armrest**	
Criteria	**weight**	**Rating**	**Weighted score**	**Rating**	**Weighted score**	**Rating**	**Weighted score**
Ease of use	5%	2	0.1	4	0.2	3	0.15
Adjustability	5%	0	0	3	0.15	4	0.2
Better posture	25%	1	0.25	2	0.5	4	1
Ease of manufacture	20%	4	0.8	2	0.4	1	0.2
Aesthetic	5%	2	0.1	3	0.15	4	0.2
Seat pan Comfort	15%	2	0.3	3	0.45	4	0.6
Backrest Comfort	15%	1	0.15	2	0.3	4	0.6
cost	10%	4	0.4	2	0.2	1	0.1
Total score			23.1	23.35		28.05	
Rank		3		2		1	
continue?		No		No		Develop	

RELATING PERFORMACE	**Rating**
Much worse than the existing workstation	1
worse than the existing workstation	2
Same as the existing workstation	3
Better than the existing workstation	4
Much than the existing workstation	5

From Table-2 concept 3 emerged as a winning concept therefore, it is the proposed design, and it will be evaluated in CATIA software using RULA. The components were created and assembled and saved in the 'STEP' format so that CATIA V5R20 can open the file for analysis.

The proposed design anthropometrical parameters for a seated human

The following are the anthropometry parameters used to develop the chair for my workstation:

a) Seat height or popliteal height (a) = (350-460)mm
b) Seat length (b) = 380mm
c) Seat width (c) = 380mm
d) Width between armrests (d) =400mm
e) Distance between armrest and seat (e) =230mm
f) The angle between the backrest and the chair's seat (α) = 105°, the angle has been taken about BS 5940

Figure-8 shows measurements (i-vi).

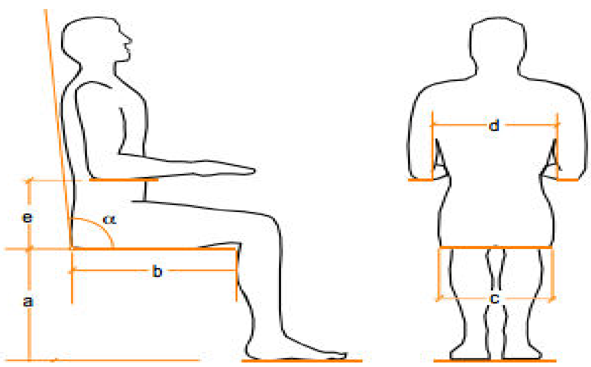

Figure-8. Seated anthropometrical parameters (Ruiz, 2007).

RESULTS AND DISCUSSIONS

RULA was conducted using CATIA V5R20; the RULA examines the following risk factors: the number of movements, static muscle work, force, working posture, and time worked without a break. All these factors combine to provide a final score that ranges from 1 to 7; each score represents the degree of injury risk and the required action to be done. Table-3 shows the RULA scale.

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Table-3. RULA score scale (Jayaram *et al*., 2005).

Level	Colour	Score	Description
1	Green	1 or 2	Acceptable posture if not maintained or repeated for long periods
2	Yellow	3 or 4	Further investigation is needed, may require changes
3	Orange	5 or 6	The investigation, and changes required soon
4	Red	≥ 7	The investigation and changes required immediately

Scores 1-2 represent good posture while 3 up to 7 represent bad posture and a design need to be worked on to improve the bad posture score. Therefore, the RULA action levels give the urgency about the need to change how a person is working as a function of the degree of injury risk.

The results in this workstation report are evaluated based on two types of predetermined posture types in CATIA:

a) Static posture
b) Intermittent posture (= < 4times/min)

These two posture types describe best, the situation that the author went through while working at a workstation.

Existing Workstation

The results of this analysis show that under static posture: the Left side of the manikin had a final score of 3. The details show red colors on wrist twists and muscles, wrist, and arm have a score of 4, and Neck, Trunk, and Leg have a score of 3. Posture A had a score of 3 and Posture B a score of 2. The Right side of the manikin under Static posture had a final score of 3. The details show a red color on the muscle, wrist, and arm have a score of 4; the Neck, Trunk, and Leg have a score of 3. Posture A had a score of 3 Posture B had a score of 2.

Under intermittent posture: both the Left and Right sides of the manikin had a final score of 3. Regarding the RULA score description in Table-3, this requires further investigation and correction. Figure-9 below shows the existing workstation while Figures 10 and 11 show the static and intermittent posture results done using RULA.

Figure-9. Existing workstation.

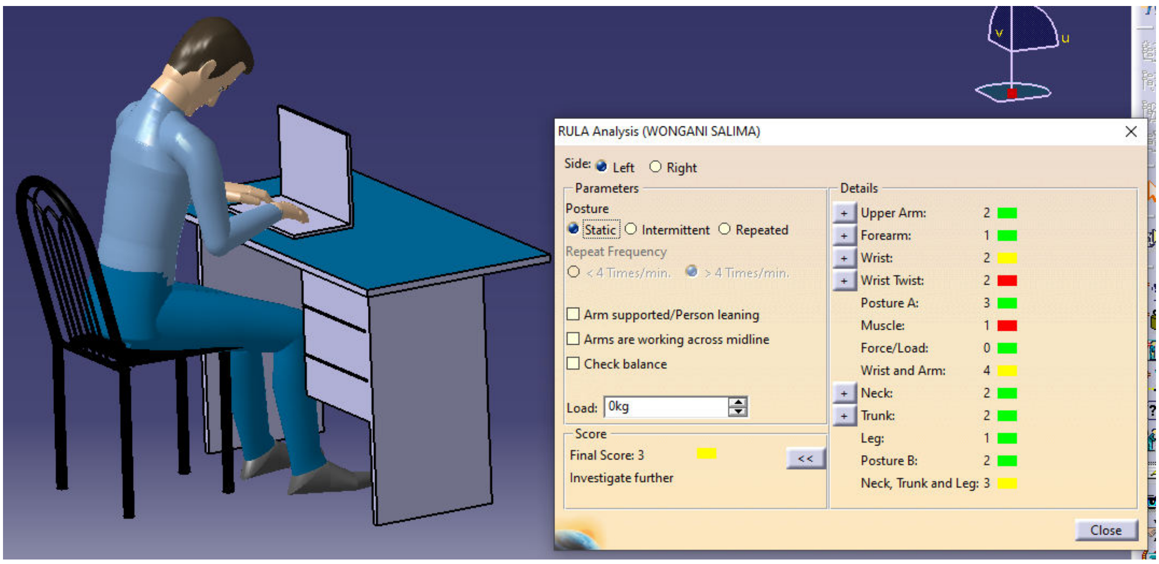

Figure-10. Existing workstation RULA score (static left).

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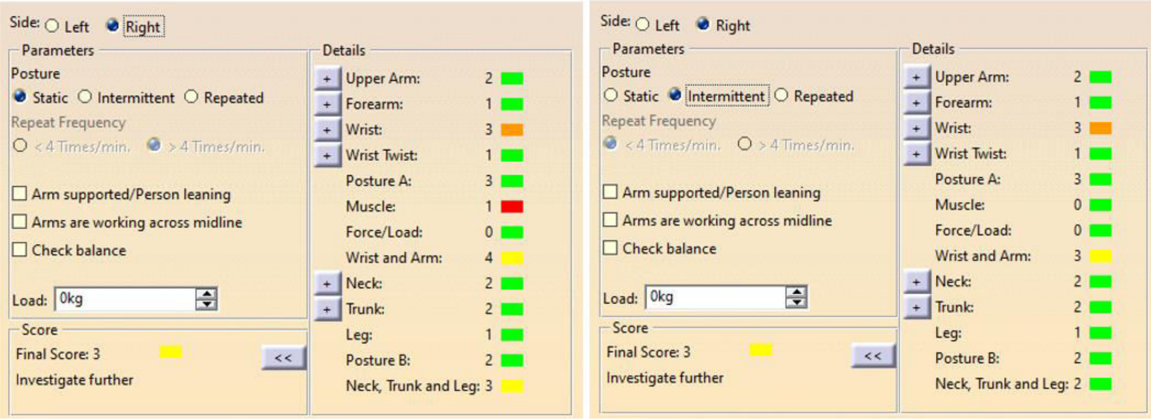
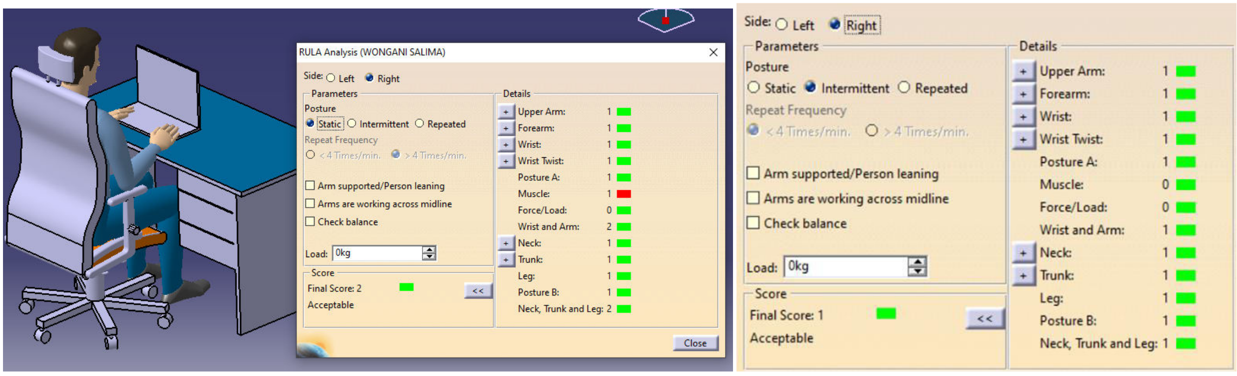


(a) (b)

Figure-11. Existing workstation RULA scores (a) static right (b) intermittent right.

Proposed Workstation (Concept 3)

The results of this analysis show that under Static posture: the Left side of the manikin had a final score of 2. The Right side of the manikin under Static posture had a final score of 2. The details show a red color on muscles, the wrist and arm had a score of 2, Neck, Trunk, and Leg had a score of 2. Posture A had a score of 1 and Posture B had a score of 1. Under intermittent posture: both the Left and Right sides of the manikin had a final score of 1. Therefore, with reference from the RULA score description Table-3, the description shows that the person is working in the best posture with no risk of injury from the work posture, therefore, the results are good. Figure-12 shows the proposed workstation results under static posture and intermittent posture.



(a) (b)

Figure-12. Proposed workstation RULA scores (a) static right (b) intermittent right.

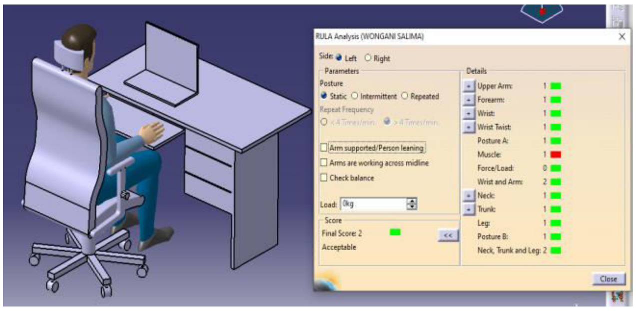
It can be observed that even though the results are good, the forearms of the manikin in Figure-12 have been supported at the elbows only unlike being horizontal as the armrests to create 90° of the elbow orientation. Therefore, the proposed workstation needs to be modified further so that it is compliant with recommended working posture as pointed out in the literature review. If the proposed design seat height is adjusted upwards the forearms will be horizontal to the armrests and will be at the same height as the desk but the limitation is that the user's head will be way above the top of the laptop and the user will be forced to bend the head downward when using the workstation hence this scenario is not desirable. Therefore, the desk will be modified by adding an adjustable platform retrofit only to the initial design that will be sliding forward and backward, up and down, to improve the proposed workstation limitation. This platform retrofit will be used to place an external keyboard and mouse to operate the laptop. Figure-13 shows the final design (improvised).

Figure-13. Final design.

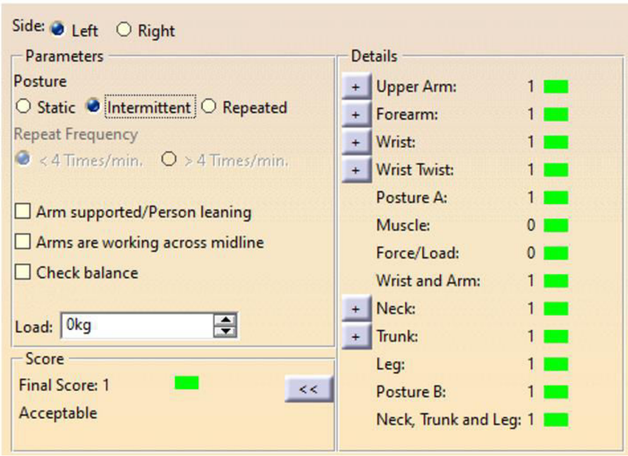
Final Workstation Design

The RULA was performed using CATIA software, by inserting a 30-percentile male manikin of the Chinese people population as the dimensions are equivalent to the author's body measurements. The platform was adjusted to depict how the external keyboard and mouse will be positioned. Then, the manikin position was maintained as in the proposed design but now in the final design; the forearms were resting horizontally on the armrests and at the same level as the platform. The results of this analysis show that under Static posture: the Left side of the manikin had a final score of 2 and the Right side had a final score of 2.

Under intermittent posture: both the Left and Right sides of the manikin had a final score of 1. The RULA score results of the proposed design and the final design are the same but the final design provides better adjustments to the user's forearms and this is in line with the 90° rule 'keep elbows at a 90° angle with wrists straight and shoulders relaxed' (Sarkar & Shigli, 2012). Figure-14 shows the final design scores for both static and intermittent right.



(a)



(b)

Figure-14. Proposed workstation RULA score (a) static right (b) intermittent right.

CONCLUSIONS

This paper studied the workstation that was used by the author to conduct online studies. The existing workstation was developed and assembled by using the actual dimensions of the workstation then it was analysed in CATIA V5R20 software using the RULA to assess the level of injury risk. The existing workstation had a RULA score of 3 both under static and intermittent posture that demanded investigation and correction. Then, a proposed design was developed to address the risk, it was designed and assembled based on the author's body dimensions while respecting the ergonomics attributes in the design, then CATIA V5R20 software was used to perform the RULA. A score of 2 was achieved under static posture and a score of 1 under intermittent posture. The proposed design proved to have an acceptable level of injury risk, but it had a limitation in adjusting the armrest to be at the height level as the desk to keep the elbows at 90°. The proposed design was modified by adding an adjustable platform on the desk to achieve the desired posture. The modified proposed design is the final design that has a final score of 1 indicating the best posture while working on the workstation.

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