Malaysian Journal of Ergonomics
Volume 1, December 2011 (31-45)

Redesign and Development of a Student's Chair Parameter at Lecture Hall for Malaysian University

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Abstract

This paper discussed on redesign and development of the existing student's chair at lecture hall in Malaysian University, The main objectives of this study were to identify the current problems of existing student's chair in lecture hall, observed and analyzed the existing design to find the critical parameter that effect their perceived level of body discomfort, and propose appropriate measures of new seat parameters according to the ergonomic requirements associated with the student's population using standard Anthropometry's data of Malaysian students and literature guidelines. Methods: Ninety students were participated in this cross-sectional study. The data was collected through the observation, distributing the questionnaire, and also interviews. Results: The results from questionnaire were analyzed with regard to the sitting posture in the lecture hall, student age, seat parameter and their weight and their correlation with the back pain. The prevalence of back pain among students was 76.67%. It was found that there are a few problems face by students while they were sitting on the chair. The most critical parameter were observed from simulation analysis, where the seating height is too high and also the seat back angle that is not suitable which may caused discomfort and back pain. The MannequinPRO software was used to analyse the current posture of students while sitting and comparison has been made for current and new seat parameters using RULA analysis. This study indicated that using the new seat parameters, the score for RULA analysis is reduce from four/five to two/two. Conclusion: Therefore, some recommendation for the new seat parameters according to guidelines suggested in literature associated with Malaysian Anthropometry for seat design was made such as adjustability of seat height, footrest and armrest in order to reduce the fatigue and backpain among Malaysian University students.

Keywords: Seat design, Malaysian University, Anthropometric data, Lecture hall

1. Introduction

Fundamental of seat is to provide stable bodily support in a posture that is comfortable over a period time, physiologically satisfactory and appropriate to the task or activity in question. In matching the seat to the user, anthropometric factors are of major importance. An appropriate match between the dimensions of the seat and those of its users is necessary for comfort, but no sufficient. Thus, anthropometric aspects must be considered in this seat design.

Ergonomics criteria related to physiology have, however, come under scrutiny, particularly in the past decade. Due in large part to Akerblom's (1948) work, ergonomics criteria related to anthropometry have long been considered a key aspect of comfortable seating. From this perspective, designers must ensure that a range of people, from small to large, fit in the seat. In general, seat designs are specified by noting, for a target population, the constraining values of appropriate anthropometric dimensions (usually 5th percentile female and 95th percentile male). Currently, the seat used in lecture hall in most of the Malaysian University are not fits and comfortable to the students. The student's population comes in all shapes and sizes. The current design of the seat is not considered for students who has big and smallest in size to sit comfort. Smaller student sometimes feel pressure on the thighs and the back of knee because of chair that are too high or too deep in the seat; discomfort and numbness in the legs and feet can follow. Larger student may have problems with chair that are too narrow to allow them enough room to alter their postures.

Therefore, the purpose of this study is to redesign and develop the seat by proposed the appropriate measures of new seat parameters according to the ergonomic requirements associated with the student's population.

2. Related Work

There is strong evidence of an association between musculoskeletal disorders, workplace physical factors, and non-work related characteristics. Non-work related characteristics include physical fitness, anthropometric measures, lumbar mobility, physical strength, medical history, and structural abnormalities of the individuals. Workplace physical factors include heavy physical work, lifting and forceful movements, awkward postures, whole-body vibration, and static work postures. Static work postures of prolonged standing, sitting, and sedentary work are isometric positions where very little movement takes place. These postures are typically cramped or inactive and cause static loading on the muscles [14].

2.1 Seat Postures

The biomechanical considerations of seated postures include the spine, arms, and legs. The muscles at the back of the thighs influence the relative position of the spine and pelvis. The location and slope of the work area influence the position of the neck, shoulders, and upper extremities, when an individual is in a seated posture. Therefore, along with the seat itself, it is essential that the work to be performed be taken into consideration [6].

A body position or posture is considered appropriate if the weight of an individual's body is transmitted to the seat with the least amount of stress on the body as possible [18]. The headrest, full-size backrest, and the seat pan should receive the weight of the head, the trunk, and the thighs, while the weight of the lower legs and feet is transmitted to the floor, suitable footrest, or in the case of a bus operator's workstation, the foot pedals.

2.2 MSDs among Malaysian students

The prevention of musculoskeletal disorders is achieved by interventions, which reduce the probability and severity of injuries. It is estimated that, through ergonomic design up to one-third of compensable low-back pain in industry can be reduced [10].

Also, Saporta [16] suggested that to minimize musculoskeletal stresses the seat should be designed such that:

i. Should permit shifting or changing of seated posture
ii. A large adjustable back support should be provided
iii. Seat surface should be accommodating, but not spongy, in order to accommodate the forces transmitted on it
iv. Adjustments in seat height and angles to be easy

All these features can contribute to good-seated posture.

3. Methodology

3.1 Subjects

The study focused on the Universiti Tun Hussein Onn Malaysia (UTHM) students as a population students from three main faculties are randomly selected as a sample. 150 questionnaires were distributed among UTHM students.

3.2 Questionnaire

The questionnaire was manually distributed among Universiti Tun Hussein Onn Malaysia students by random sampling. The question was divided into three sections. The first section dealt with background information such as height, weight, age, gender, level of education, and marital status. In section two the question was regard to the student satisfaction and their ergonomic understanding of the physical surrounding and identifies the student's needs and problems. In the section three, the question more to gain the comment and suggestions that can solve the chair design problems.

3.3 Sampling and observation

In this study, three different lecture halls were taken as samples to measure the seat design. The dimensions for the seat pan, backrest and seat table were measured and the average values were calculated. The layout of the seat was also observed. The seat design of the samples taken was typical of the seat used in the University lecture halls.

3.4 Body part symptom survey

Three students that were involved in using these seats were interviewed on the prevalence of any musculoskeletal pain that they experienced that can be related to the design of the seat used. Body part symptom figure was used based on the sitting posture for the students to indicate the body parts experiencing problems namely the neck and head, shoulder, upper back , arm and hand, lower back, thigh, knee and ankle and leg. The frequency of the response for each part was calculated.

3.5 Modelling and evaluating the seat design

Both seat designs were then modelled into AutoCAD software version 2008. The AutoCAD software was used to design the current and recommended seat . For the simulation, Ergonomics Modeling Software MannequinPRO™ was used. In simulation using the RULA tool available in the software, the seats were evaluated for their performance and comparisons were made.

RULA analysis

The Rapid Upper Limb Assessment (RULA) is one of the ergonomic techniques for evaluating individuals' exposures to postures, forces and muscle activities that have been shown to contribute to Repetitive Strain Injuries (RSIs). Use of this ergonomic evaluation approach results in a risk score between one and seven, where higher scores signify greater levels of apparent risk. It was developed to detect work postures or risk factors that deserve further attention [11].

The RULA analysis examines the following risk factors: 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.

1. 1 and 2: (Green) Indicates that the posture is acceptable if it is not maintained or repeated for long periods of time.
2. 3 and 4: (Yellow) Indicates that further investigation is needed and changes may be required
3. 5 and 6: (Orange) Indicates that investigation and changes are required soon.
4. 7: (Red) Indicates that investigation and changes are required immediately.

3.6 Current seat measurement

The current seat was measured as shown in Figure 1**:** a. backrest width, b. backrest height, c. seat pan length (depth), d. seat pan width, e. seat height, f. seat-to-table distance, g. back-to-table distance, h. seat-to-seat distance, i. table width, j. table length, k. table depth, l. angle of inclination, m. distance between the backseat to table.

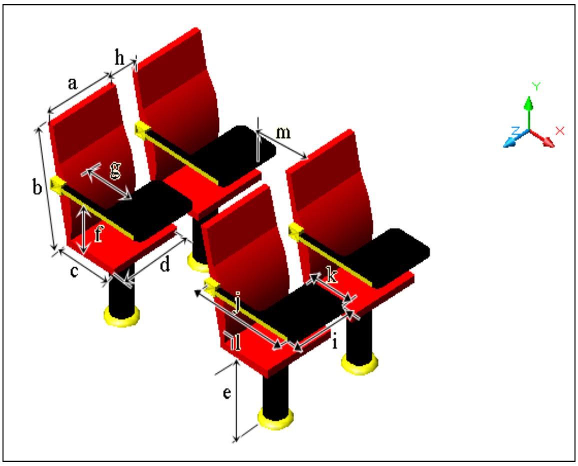

Figure 1: The Current Seat Parameters Design in Lecture Hall.

4. Results and Discussions

4.1 Questionnaire

From 150 questionnaires distributed only 90 questionnaires has been returned. That means 60% of response rate. The data shows that the numbers of respondents are equal between male and female. Most of the respondents age are in the 21 – 23 years (46, 51.11%), followed by 24-29 years (24, 26.67%) and 18-20 years (20, 22.22%).

For the weight of respondents, the highest respondent's weight is between 50-60kgs (36, 40%) and followed 60-70kgs (20, 22.22%), then 40-50kgs (18, 20.0%), weight between 70-80kgs (11, 12.22%) and for weight more than 80kgs and less than 40kgs are gives the lowest respondents (3, 3.33%) and (2, 2.2%) respectively.

The range of respondents height between 160cm-170cm gives the highest percentage that is 42.22%, followed by height between 150cm-160cm that is 31.11%, 18.89% for height between 170cm-180cm, 5.56% for height between 140cm-150cm and 1.1% for the range height less than 140cm and more than 180cm and above.

The results shows that the highest percentage score (73.33%) from respondents sitting more than 2 hours per day in lecture halls and followed by 25.56% of them are sitting between 1-2 hours and lowest percentage is 1.1% for sitting below than 1 hour.

The level of comfortable while studying in lecture halls shows that 64 respondents (71.11%) are not comfortable with their study surrounding in lecture hall. The respondents also agreed that it was caused by the condition of the chair, spacing between seat and table and the space between the next chair and also by an air-conditioning system. Only 26 (28.89%) of respondents feel comfortable with their study surrounding in lecture hall.

4.2 Sampling and Observation

For the seats in the three different lecture halls used as sample, it was found that there were no headrest. The headrest is important to support the weight of the head in order to reduce amount of stress on the body. Therefore the headrest should be considered towards reducing fatigue among students.

4.3 Body part Symptom survey

The results are they always feel not comfortable with the existing chair's design in lecture hall. Their experienced about 1-2 hours of lectures give some back pain, discomfort legs, and lacking energy while sitting on the chair. Students claimed that they experience on back pain and feel such pressure at buttocks especially those who are pregnant. Also the space between the table and back rest not fix enough.

From figure 2, it shows that most of the students (61%) frequently feel uncomfortable with their legs during sitting. The second frequently highest is happen at the thighs region (50%). It is caused by the current design problems where the seat height may not suitable enough for them. From the diagram, it shows the number of them often aching or lacking energy at their buttock. They rarely feel uncomfortable at the upper back and mid back this maybe due that the chair has the lumbar support so the aching will decreased. The numbers of them also have problems with their neck because the backrest is too low and the seat angle position is not design properly.

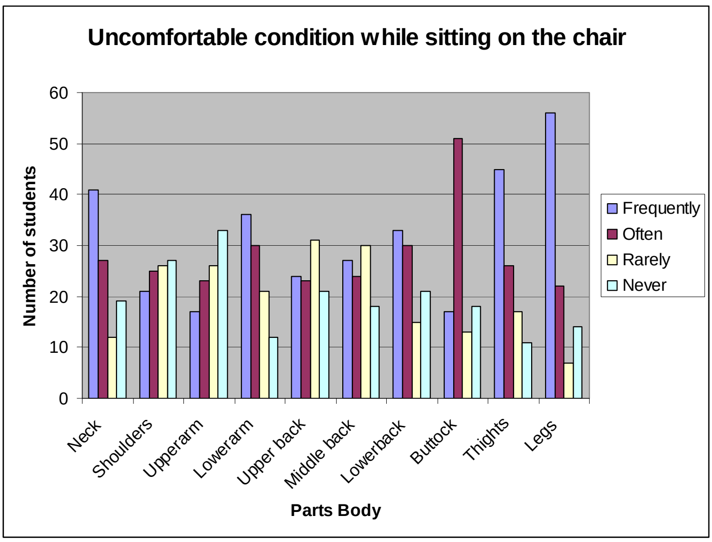

Figure 2: Parts Body Condition at Current Chair.

4.4 Current seat measurement

The results of the current seat measurement are shown in Table 1. These results will be compared with the relevant anthropometric data to recommend a new seat design.

Table 1: The Average Dimensions of Current Seat Parameters Design at Different Lecture Hall

Item	Features	Average dimensions (cm)
a	Backrest width	43.97
b	Backrest height	33.03
c	Seat pan length (depth)	42.1
d	Seat pan width	43.2
e	Seat height	28.1
f	Seat-to-table distance	19.17
g	Back-to-table distance	35.33
h	Seat-to-seat distance	8.2
i	Table width	27.5
j	Table length	26.7
k	Table depth	63.93
l	Backrest inclination angles	91˚
m	Distance between the backseat	13.5
-	Armrest	None
-	Footrest	None
-	Headrest	None

4.5 Redesigning the current seat

a) Seat pan

Seat height for the current seat was found in the range of 330mm to 421mm with fixed condition. In general, the optimal seat height for many purposes is close to the popliteal height and where this cannot be achieved a seat that is too low is preferable to one that is too high. For many purposes, the 5th percentile female popliteal height represents the best compromise [15]. Based on the Malaysian student's anthropometrics data [20], for the 5th and 95th percentile popliteal height, the seat height should be 330mm to 466mm regarding to.

The current seat depth is approximately 420mm. From literature, if the depth is beyond the buttock-popliteal length, the user will not be able to engage the backrest effectively without unacceptable pressure on the backs of the knees. Also, the deeper the seat, the greater the problems of standing up and sitting down will be. The lower limit of seat depth is less easy to define. As little as 300mm will still support the ischial tuberosities and may well be satisfactory in some circumstances [15]. Therefore, based on the Malaysian student's anthropometrics data obtained, the seat depth should be 390mm by referring to the 5th percentile male popliteal-buttock depth.

To support the buttocks, a width that is some 25mm less on either side than the maximum breadth of the hips is all that is required. Hence 350mm will be adequate. However, clearance between armrests must be adequate for the largest user. The hip breadth of the 95th percentile male will be considered [15]. Since the current seat width is 432mm, it is acceptable because the 95th percentile male Malaysian hip breadth for the students is 380mm.

b) Backrest

The backrest parameters consist of backrest width, height, lumbar support and backrest inclination angles. The current backrest minimum height is 330mm. Pheasant [15] stated that, the medium-level backrest is used to supports the upper back and shoulder regions. For support to mid-thoracic level an overall backrest height of about 500mm is required and for full shoulder support about 650mm (95th percentile male values rounded up). Whatever its height, it will generally be preferable and sometimes essential for the backrest to be contoured to the shape of the spine, and in particular to give positive support to the lumbar region in the form of a convexity or pad. Based on the 95th percentile male sitting shoulder height, the height of the backrest should be 651mm.

The backrest width of current seat is at approximately 440mm. The seat back width should allow users to be supported without arm interference. The shape should be convex from top to bottom to conform to the normal lordosis, and concave from side to side to conform to human anatomy and support the occupant in the seat [6]. Thus the 95th percentile male elbow-to-elbow breadth measurement of 560mm is recommended to give full support for the back.

The high complaint of lower back pain is most probability due to the lack of lumbar support. Reiteration of high muscle activity at lumbar produces fatigue of lumbar muscles, so that the subjectively sensed fatigue is reported at lumbar [16]. The lumbar support should be placed in the lumbar region to achieve a more normal lordotic curvature when in the seated posture. In order to provide as much comfort as possible, the support should be adjustable in both height and size, and large enough to accommodate a wide range of users [16].

In the current seat design, the lumbar support is not adjustable. The lumbar support should be large enough to accommodate a wide range of users [16]. Since the lumbar support range of 5th percentile and 95th percentile male Malaysian anthropometrics data was not available, by using ratio scaling, (using 95th and 5th percentile stature and lumbar support values for the Japanese population) the lumbar support height adjustable range was calculated and a range of 180mm to 280mm was found.

The most important factor in reducing low back stress is the inclination angle of the seat back itself. The height and inclination of the seat pan combined with the position, shape, and inclination of the backrest influences the resulting seated posture [16]. Pheasant [15] stated that a backrest inclination of about 110 degrees is considered an appropriate posture, however, greater inclination may be desirable by the user. The backrest tilt angle adjustment should be independent so that there is little or no effect on the front seat height or angle. Furthermore, increasing the angle between trunk and thighs improves lordosis. The backrest inclination for current seat is approximately in the range of 10-15^{o} from the vertical seat reference point. Thus, no changes are required.

c) Armrests

Since the current seat was not provided with an armrest, this should be considered as an option. Pheasant [15] cited that armrests might give additional postural support and be an aid to standing up and sitting down. It also provides support for resting the arms to prevent or reduce arm, shoulder, and neck fatigue. A gap of perhaps 100mm between the armrest and the seat back may, therefore, be desirable. An elbow rest that is somewhat lower than sitting elbow height is probably preferable to one that is higher, if a relaxed posture is to be achieved. The elbow rest at 200-250mm above the seat surface is generally considered suitable.

The height of the armrest was set at 5th percentile male elbow-rest height at 600mm from floor level and approximately 210mm above the seat surface. The adjustability of the armrest is proposed to accommodate the 95th percentile male as well. Therefore the range of the adjustable armrest would be 210mm-230mm above seat surface as recommended by Rosnah et al. (2006). The armrests should be able to be moved out of the way in order to accommodate bus driver preferences.

d) Simulation results

The drawings of the seat designs were done in the CAD environment, exported into Ergonomics Modeling Software MannequinPRO™. The 3-D human model was edited with the Malaysian student's anthropometry data. All the missing data were calculated using the ratio scaling method by referring to the Japanese population. Thus, the edited human model called 'manikin' in the software represents the Malaysian student's anthropometry data population. The human is located on the seat using H-point and Seat Reference point (SRP) relationship [21].

The study position was simulated under kinematics constrains and adjustable components were located iteratively until the human-workstation model satisfied ergonomic principles such as visibility, reach, and comfort. A comparison of current seat design for 5th percentile female and 95th percentile male are shown in Figure 2.

The simulation of the current seat showed that it does not provide adequate backrest support for the 5th percentile male as the dimension of existing seat pan length is 420 mm, but the popliteal-buttock depth is only 390 mm.

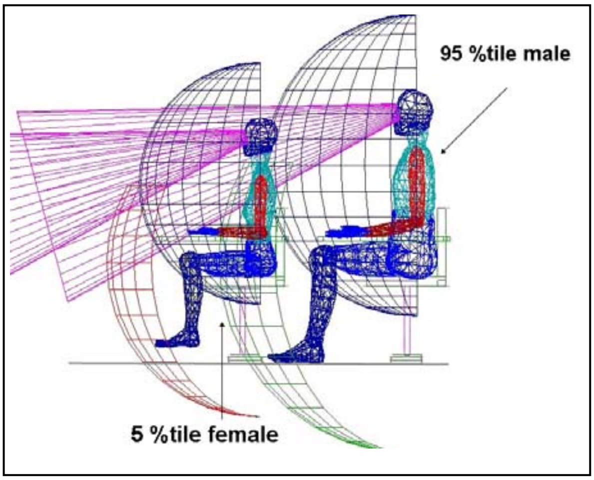

Figure 2: Comparison of Current Seat Design for 5th Percentile Female and 95th Percentile Male.

Also, it can be seen that for the current seat an extra leg support is required, indicating that the seat height is too high for the 5th percentile drivers. When support for the leg is inadequate, the pressure distribution on the thighs will increase. Blood circulation is restricted and this contributed to thigh fatigue. Leg support is critical to better distribute and reduce the load on the buttocks and the back of the thighs. The weight of the lower legs should not be supported by the front part of the thighs resting on the seat. Pressure applied to the front part of the thighs, the portion close to the knees, can result in swelling of the legs and pressure on the sciatic nerve [21].

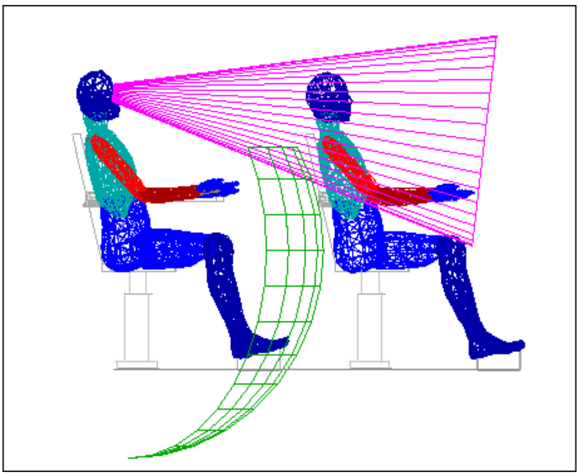

Figure 3: Range of Leg Reach, and the Minimum View Cone (Side View) of Proposed Seat Design 95th Percentile Male.

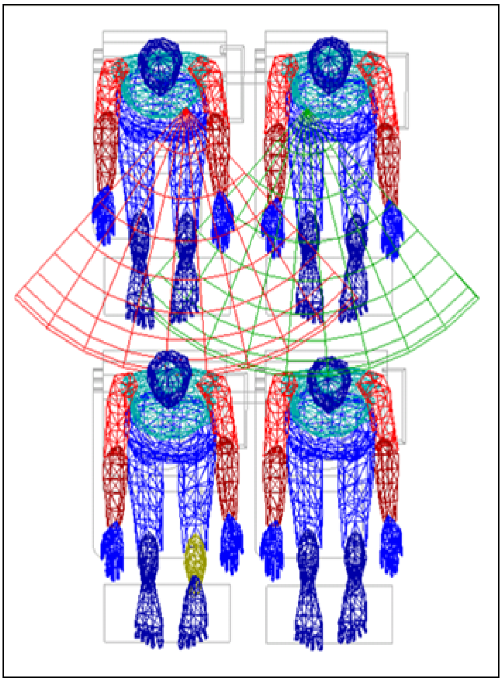

Figure 4: Range of Leg Reach, and the Minimum View Cone (Top View) of Proposed Seat Design 95th Percentile Male.

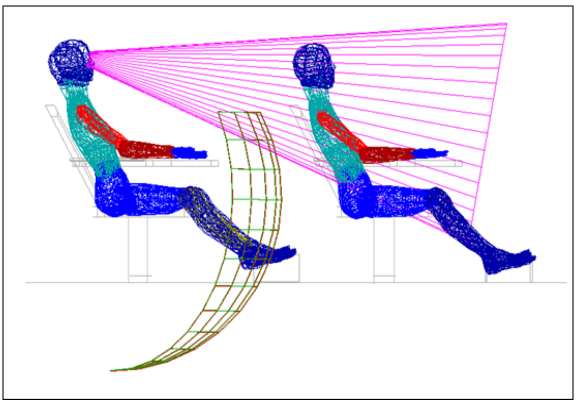

Figure 5: Range of Leg Reach, and the Minimum View Cone (Side View) of Proposed Seat Design 5th Percentile Female.

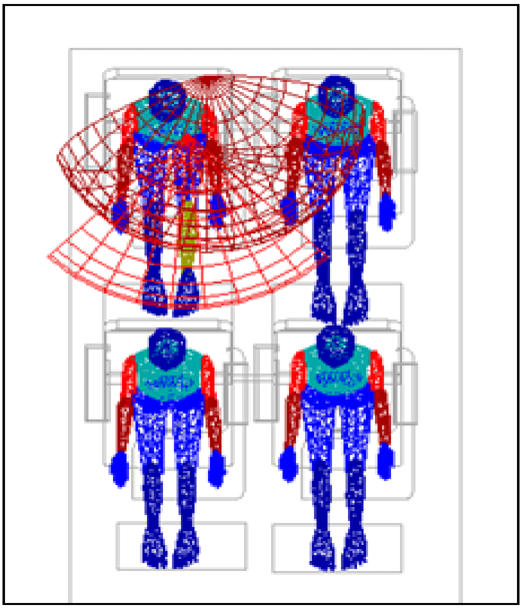

Figure 6: Range of Leg Reach, and the Minimum View Cone (Top View) of Proposed Seat Design 5th Percentile Female.

e) RULA analysis

RULA or The Rapid Upper Limb Assessment Analysis examines the following risk factors: 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. The result of the RULA analysis (Table 2) showed that the final score of posture for current seat is five/four.

Table 2: The RULA Analysis for Posture of Current Seat and Proposed Seat

Activity	Before Intervention	After Intervention
1. Upper arm right	-1	+1
2. Lower arm right	+1	+2
3. Wrist right	+1	+1
4. Wrist twist right	0	1
5. Muscle use/ Force & Load	0	0
6. Upper arm left	+1	+1
7. Lower arm left	+1	+2
8. Wrist left	+1	+1
9. Wrist twist left	0	1
10. Muscle use/ Force& Load	0	0
11. Neck	+1	+1
12. Neck twist	+1	+1
13. Neck side bend	+1	+1

14. Trunk	+2	+1
15. Trunk twist	+1	+1
16. Trunk side bend	+1	+1
17. Legs	+2	+1
18. Muscle use/ Force &Load	+1	0
GRAND SCORE (right/left)	5/4	2/2

According to the literature, a RULA score of five/four indicates that further investigation is needed and changes may be required soon. With the recommended seat, the final score was reduced to two (Table 2). This indicates that the posture is acceptable if it is not maintained or repeated for long periods of time.

Therefore, from the simulation results, the recommended seat design is acceptable as it can help students to reduce fatigue while studying in lecture halls, especially in improving the posture arm and wrist and for the trunk and legs. A more comfortable seat will increase the learning performance of the students.

5. Conclusion and Recommendations

A seat designed based on anthropometry of the users showed that it has improved the ergonomics of the seat. Such seat is more comfortable as shown by the RULA analysis. The next step is to fabricate and test the seat among the students. A summary of the design parameters for the recommended seat is given in Table 3. The dimensions of the recommended seat parameters will be able to accommodate the 90 percent of Malaysian student's population.

A seat that is provided with proper support, adjustable height, reclined seat back, among others, can increase the comfort of the students, improving their study performance, and reduce fatigue. Therefore the use of the seating parameters option have dramatically increases the time during which students will be able to pursue daily activities in their studies without limitations imposed by intolerable discomfort or pain.

Table 3: Summary of Recommended Seat Design Parameters

Seat dimension	Current measurement (cm)	Recommended measurement (cm)
Backrest width	43.97	47
Backrest height	33.03	60
Seat pan length (depth)	42.1	38
Seat pan width	43.2	40
Seat height	28.1	40
Seat-to-table distance	19.17	22
Backseat-to-table distance	35.33	30
Seat-to-seat distance	8.2	15.1
Table width	27.5	31.5

Table length	26.7	42.5
Table depth	63.93	63.93
Seat to back angle	91˚	100˚
Back-to-back seat	13.5	13.5
Armrest	None	Required
- Width		9
- Depth		27
Footrest	None	Required
- Distance from footrest to seat		30

Acknowledgement

The authors would like to thanks Universiti Tun Hussein Onn Malaysia for supporting this research under the Short Term Research Grant.

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