A study on the suitability of science laboratory furniture in Malaysian secondary school

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Abstract

Furniture has a significant effect on human health. Thus, it is essential to use anthropometric data to guide the design of school furniture as the interface of furniture and the user is perhaps the most critical factor for human comfort. School science laboratory furniture in Malaysia is typically not designed to accommodate the dimensions of the individual student. A one-size-fits-all philosophy has been adopted in the industry. This study examine possible mismatch between the individual body dimensions of students and the school science laboratory furniture they use. The objective is to determine whether this type of furniture is well-designed and promotes good sitting posture and also the suitability of the furniture with the task performed. It involves 120 students from multiple races with age range from 16 to 19 years and no physical disabilities. 7 dimension of the school science laboratory furniture and 7 parts of the body segment or anthropometric data for each of the student have been measured using standard anthropometer set and measurement tape in order to allow a comparison of the student ergonomic needs with the design features of the furniture. Data indicates a substantial degree of mismatch between the students' bodily dimensions and the laboratory furniture available to them. Therefore, the identification of individual anthropometric requirements among school student of the same age could be a useful tool for the arrangement of the issue of school science laboratory furniture design and allocation.

Keywords: anthropometry, ergonomics, laboratory furniture, Malaysian secondary school, students

1. Introduction

Human health risk is varying from case by case basis. There are many factors that can influence human health such as the work environment, external factors and also personal dispositions [1]. In ergonomics point of view especially in anthropometry study, incorrect product and workplace adjustments to anthropometric characteristics can lead to discomfort, pain and disorders in neck, shoulder, back, arm, hand and wrist and result in musculoskeletal diseases [2]. Musculoskeletal disorders due to these reasons have been found in different contexts such as in the factory, office as well as in a school environment [3]. The interface of furniture, equipment and personnel is perhaps the most critical factor for human comfort in the workplace. In order to determine that the furniture is safe to use, the furniture designer need to consider the anthropometry of the specific user as well as the suitability towards the activity. There are few different types of furniture that have been used in school which depend on the location and the purpose of that furniture for instances, classroom, library, canteen and science laboratory.

A laboratory is like any workplace, should be oriented to the basic needs of the user in terms of creature comforts, ergonomics, accessibility, life safety and environmental features. Unfortunately, these common workplace amenities are often neglected in many laboratories today including school science laboratory because of several opposing forces that work against them. The design of laboratory environments and furniture with respect to their occupants is often shortsighted. This is because laboratory furniture from manufacturers is typically not designed to accommodate the dimensions of the individual user throughout the country because such furniture is less costly to manufacturer and lessens their inventory problems. On the other hand, anthropometric measures vary among individual, races and nations and it changes over time as populations and their environmental conditions change. Due to that, it is very important to get the students' body measurement and to alter the school furniture size so that the furniture provided is suitable with the user and enhance good sitting and standing posture.

During the past decade ergonomic research has focused specifically on the design of school furniture based on the biomechanics of the human body. Many researchers around the world dealt with the principles for the design of furniture in the classroom as per summarized in Table 1. However, not much attempted been made to study the design of furniture in school science laboratory which is also be widely used by students for prolonged periods of time. In our country context, secondary students in science field have spends most of their learning time in the laboratory as much as in the classroom.

Table 1: Previous studies between student anthropometry and classroom furniture design

No.	Research Topic	Country
1.	Static anthropometric characteristics of students' age range 6 - 11 in Mazandaran province and school furniture design based on ergonomics principles [4]	Iran
2.	Mismatch of classroom furniture and student body dimensions [3]	USA
3.	Classroom furniture dimensions and anthropometric measures in primary school [5]	Greece
4.	Sitting habits in elementary schoolchildren: a traditional versus a "Moving School" [6]	Belgium
5.	A prototype of an adjustable table and an adjustable chair for schools [7]	Republic of Korea
6.	Match between school furniture dimensions and children's anthropometry [8]	Greece
7.	An analysis of biomechanical and anthropometric parameters on classroom furniture design [9]	Turkey
8.	Do ergonomically designed school workstations decrease musculoskeletal symptoms in children? A 26-month prospective follow-up study [10]	Finland

From the literature review, many researchers have tried to establish recommendations for the theoretical principles that relate classroom furniture design to school children's anthropometry, and some have also attempted to define the 'appropriate' dimensions for school furniture based on anthropometric measurements. According to [11], based on anthropometric data, every country can design furniture for their own fitting schoolchildren. This would require up to date measures from the relevant population. Base on that, a study has been made to evaluate mismatch percentage between Malaysian secondary students' anthropometry with existing school science laboratory furniture and also the new design of furniture that being proposed by manufacturer to government.

2. Methods

2.1 Sample

This study was conducted in a government secondary school, located in Selangor. Subject consisted of 120 students (57 males and 63 females) with age ranged 16 to 19 years and with no physical disabilities. The students were selected based on the duration of time that they spent in the science laboratory for learning purpose which is higher compared to other student. This been done by calculate the total number of hours for science stream students that using laboratory to learn physics, chemistry and biology in a day. Student age, gender and races also have been taken for the purpose of this research. For the furniture measurements, two different types of chair / stool and table which have been labelled as 'old' and 'new' were selected. The furniture with 'old' label chosen is because currently widely used in most of the government school while furniture with 'new' label will be supplied in future by the manufacturer that been awarded tender for providing furniture at new schools that build by government. Measurement has been conducted to allow a comparison of the subject ergonomic needs with the design features in order to compare the suitability between old and new furniture.

2.2 Measurement Technique

Static anthropometry measurement was implemented. Measurements were taken in standard sitting and standing positions, with student barefooted and wearing school uniform. In order to improve the accuracy of the measurements, all the measurements were taken by two permanent assistants (one for each gender) with the assistance of researcher as an observer and data-recorder.

2.3 Procedures

Student body dimension measured using standard anthropometer set when the student seated erect on a flat horizontal surface, their lower and upper legs were at right angles (knees bent at 90°) and feet (without shoes) were placed flat on the floor. Student height measurements were taken once the student stand erect barefooted. Chair and table dimension were measured with a measurement tape. Comparison been made between student anthropometry measurement with the relative furniture dimension. Data been analyzed by calculating the mean value, maximum and minimum value, standard deviation value and also the percentile value using 'Minitab' software. In this study, 5th percentile and 95th percentile was selected as a limit range. After that, the anthropometric measurements and furniture dimensions were combined to determine whether there is match or mismatch between them or act as incompatibility between the dimensions by using quantitative equation.

a. Popliteal Height (P) and Seat Height (SH) Mismatch
   Equation for this mismatch was defined by [3]. According to [3], mismatch for this combination occur when the seat height was either > 95% or < 88% of the popliteal height. This allows for popliteal clearance of between 5 and 12% of popliteal height.

b. Buttock-Popliteal Length (PB) and Seat Depth (SD) Mismatch
   Reference [3] defined mismatch between this combination when the seat depth was either > 95% or < 80% of the buttock to popliteal length. A well-fitting chair requires both a seat height between 88% and 95% of a student's popliteal height and a depth of between 80% and 95% of the students' buttock-popliteal length.

c. Hip Breadth (H) and Seat Width (SW) Mismatch
Reference [8] mentioned that seat width should be at least 10% (to accommodate hip breadth) and at the most 30% larger than hip breadth (for space economy). Mismatch happen when seat width was either > 130% or < 110% of the hip breadth.

d. Shoulder Height (S) and Backrest Height (BH) Mismatch
Equation by [8] recommends keeping the backrest lower than the scapula or at most on the upper edge of the scapula (60–80% of shoulder height). Mismatch is defined when backrest height was either > 80% or < 60% of the shoulder height.

e. Knee Height (K) and Table Clearance (TC) Mismatch
A mismatch was defined by [3] as occurring when a desk was less than 2 cm higher than the knee height. For users comfortable, desk–knee clearance should exceed 2 cm.

3. Results

3.1 Anthropometric Measurements of the Students

Table 2 summarized the results of 120 students' anthropometric data. For the purpose of analysis, the data are presented in mean, standard deviation, maximum and minimum value and also 5th and 95th percentile value.

Table 2: Anthropometric measures of overall students (n=120), values in cm unit

Anthropometric Measurements	Mean	SD	Max.	Min.	P5	P95
1. Stature (or height)	163.5	9.0	185.0	144.0	151.0	178.0
2. Shoulder height (S)	56.5	5.0	75.0	47.5	50.0	64.0
3. Elbow rest height (E)	24.6	3.3	33.0	17.0	20.0	30.0
4. Knee height (K)	49.8	3.7	59.0	39.0	44.0	56.0
5. Popliteal height (P)	41.9	3.5	50.0	34.0	36.0	48.0
6. Buttock-popliteal length (PB)	46.1	3.6	57.0	37.0	41.0	52.1
7. Hip breadth (H)	37.8	6.7	65.0	28.0	30.0	51.1

From Table 2, mean value for student's height is 163.5 cm while the standard deviation value for students' height is 9.0 cm. This means, student height difference is larger where 90 percent of the students' height is between 151.0 cm to 178.0 cm. Table 3 summarized students' anthropometric data according their gender where 57 students are male and another 63 students are female.

Table 3: Anthropometric measures according students gender, values in cm unit

Anthropometric Measurements	Male		Female	
	Mean	SD	Mean	SD
1. Stature (or height)	170.3	7.2	157.4	5.2
2. Shoulder height (S)	59.7	4.4	53.5	3.5
3. Elbow rest height (E)	25.1	3.6	24.1	3.0
4. Knee height (K)	51.9	3.1	47.9	3.1
5. Popliteal height (P)	43.7	3.3	40.2	2.8
6. Buttock-popliteal length (PB)	45.7	3.3	46.4	2.8
7. Hip breadth (H)	38.8	8.6	36.9	4.2

Table 3 shows that female anthropometric measurement value is smaller than male anthropometric value in all characteristic except buttock to popliteal length. That's why female value for a particular dimension usually represents the smallest measurement for design in a population while male value may represent the largest dimension from the 90% of the population. Besides that, standard deviation value shows measurements different between each individual for female students are lower than male students.

3.2 School Science Laboratory Furniture Dimensions

The school science laboratory furniture in this study consists of two types, the 'old' and the 'new' type as per Figure 1 and Figure 2. The critical dimensions of the furniture's (chair/stool and table) are summarized in Table 4. Since type of the chair that used in the laboratory is a stool type, vertical distance from footrest to the highest point on the front of the seat and the vertical distance from the footrest to the bottom of the front edge of the table are more important in determine the mismatch compare to distance from the floor. This is because student feet were placed on the footrest while seating on the stool not flat on the floor due to stool height is higher than a normal chair.

Table 4: Dimensions of school science laboratory furniture, values in cm unit

Furniture Measurements	Dimensions (cm)	
	Old Type	New Type
1. Seat height (SH)	60.0	56.0
2. Footrest height (FH)	41.0	41.0
3. Seat depth (SD)	26.0	42.0
4. Seat width (SW)	29.0	45.0
5. Backrest height (BH)	-	40.0
6. Table height (TH)	92.0	90.0
7. Table Clearance (TC)		
a. From Footrest	55.0	73.5
b. From Floor	74.0	88.5

3.3 Comparison between Student Anthropometric Measurements and School Science Laboratory Furniture Dimensions

Match or mismatch was calculated base on equation that mentioned in the method section. Table 5 shows the number and percentage of students whose measurements match or did not match with the old type furniture.

Table 5: Number and percentage of students who match and mismatch with the old school science laboratory furniture

Comparison between anthropometric measurements and furniture dimensions	Match		Mismatch	
	Students	%	Students	%
1. Seat height (SH) and Popliteal height (P)	24	20.0	96	80.0
2. Seat depth (SD) and Buttock-popliteal length (PB)	-	-	120	100.0
3. Seat width (SW) and Hip breadth (H)	-	-	120	100.0
4. Backrest height (BH) and Shoulder height (S)	-	-	120	100.0
5. Table clearance (TC) and Knee height (K)	92	76.7	28	23.3

Figure 1: Old type chair/stool and table

Table 5 reveals that none of the student measurements were in proportion to the chair or stool in depth and width. In fact there is no support to students' spine or back which may affect student health when the chair or stool is used in a longer period of time due to no backrest provided. Only 20.0% of the students in the sample were match to the chair or stool height and 76.7% of the students were matched to the old type of table clearance. As is apparent, the chairs or stools were too deep and narrow for all students and too high for 80.0% of them. There was also knee clearance problem for 23.3% of the students.

For new type furniture suitability, Table 6 shows the number and percentage of students whose measurements match or did not match the dimensions of the new type furniture.

Table 6: Number and percentage of students who match and mismatch with the new school science laboratory furniture

Comparison between anthropometric measurements and furniture dimensions	Match		Mismatch	
	Students	%	Students	%
1. Seat height (SH) and Popliteal height (P)	24	20.0	96	80.0
2. Seat depth (SD) and Buttock-popliteal length (PB)	72	60.0	48	40.0
3. Seat width (SW) and Hip breadth (H)	50	41.7	70	58,3
4. Backrest height (BH) and Shoulder height (S)	111	92.5	9	7.5
5. Table clearance (TC) and Knee height (K)	120	100.0	0	0.0

From Table 6 results indicate that seat depth of chair or stool was appropriate for 60.0% of the students and for seat width, 41.7% of the students' match with the chair or stool. Only 20.0% of the students' measurements were compatible with the new type of chair or stool in height, while most of them or in percentage 92.5% had a good match in terms of shoulder height and backrest height for new type of chair or stool. Besides that, new type of table gives the students sufficient space for their knee clearance because result shows all of them match with the height of table clearance.

Figure 2: New type chair/stool and table

4. Discussion

The results indicate a mismatch between anthropometric measurements of the students who participated in this study and the school science laboratory furniture available to them. Majority of the students are sitting on chairs or stools that are too high for them. This is because both model either from old type design or new type design have same footrest height even though seat height dimension give a different value. Only table clearance is acceptable for the vast majority of the students. The number of student whose measurements have a good match with the new type design of school science laboratory furniture in seat depth, seat width and backrest height is much higher compare to the old type furniture where none of them are match. In othe words, new furniture is much more suitable for school science laboratory usage rather than old furniture. That's why in study being done by [12] revealed that the wood stools (old type chair) uses in the laboratory were not comfortable to sit on in a long time during teaching and learning process. This statement come from teachers' perspective when they being interviewed about the constraint that they faced while teaching science especially related with the science laboratory learning environment in Malaysia.

According to the bulletin that releases by [13] suitable height for laboratory workbench or table in doing light work is from 86.4 to 94.0 cm. Prior to that, some general comparison can be made between the results from this study and recommendations in the literature whereby table height that been measured in this study either from old type or new type are in the range or specification where the values is 92.0 cm and 90.0 cm. Comparison was not been done in this area although there is an equation to relate elbow height and table height to find the suitability. This is because, data collected is only suitable for seating design workstation while laboratory is a combine type of workstation where user or student may sit or stand at a time. However, there is an important aspect that must be take a look at where finding an acceptable table-chair combination as a solution or use variable-height tables rather than fixed-height tables in daily practice and these be adjusted for each task as per recommend by [14]. Furthermore, performing tasks at an appropriate workstation table height would help reduce low-back loading and potentially disability [14].

School science laboratory is expensive when it comes to equipments, furniture and maintenance, therefore carefully planning is needed to cut down the cost. One of the important features recommended is to incorporate flexibility in school science laboratory design. Ideas for flexible designs of school science laboratories range from movable furniture to movable internal walls and from peripheral to central location of services. However, total

flexibility in each and every feature cannot be attained and compromises have to be made and creative design and construction solution are needed [15].

Results from this study may useful for future activity. Designer or Malaysia furniture manufacturer may take into account some important body measurements that may be used in the ergonomic design of school science laboratory furniture. For Malaysia students that age range between 16 to 19 years old, 90% of the students in the sample have popliteal height values between 36.0 and 48.0 cm and values for the buttock to popliteal length in a sitting position is from 41.0 to 52.1 cm. While values for hip breath is from 30.0 to 51.1 cm. Although, sample of students not distribute well among the races whereby student percentage ratio for Malay, Indian and Chinese that involve in this study are 84.2%, 13.3% and 2.5%, results value can be treat as reference. At least in future, seat height, seat depth and seat width for a laboratory chair or stool can be design appropriately and ergonomically according to the student body dimensions rather than no guidelines.

5. Conclusion

The present study found that there is a substantial discrepancy between the students' anthropometric data and the dimensions of the school science laboratory furniture. Selecting the proper furniture for a large group of student is both impractical and difficult and for this reason adjustable school science laboratory furniture would be preferable. As a whole, it seems useful to continue to strive for ergonomic furniture in the school science laboratory. What is taken for granted today for almost every of workplace; it must provide the ergonomic surroundings for maintaining the health and psycho-physical well being of the user and it's neglected in schools for economic reasons and ignorance. Therefore, school science laboratory should be equipped with furniture which is adjusted to the individual proportions of the students and enhances dynamic sitting or standing.

6. References

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