Evaluation of Classroom Furniture from Ergonomic Design Considerations

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Abstract: The present study is aimed to evaluate the different dimensions of classroom furniture with respect to anthropometric measures of students. For this purpose, 982 students in the age group 10-16 years are selected from 3 different schools from Solapur city. Various anthropometric measurements of the students are taken. Similarly, Dimensions of the existing desks available in the respective classrooms were also measured. For the ergonomic evaluation of classroom furniture, match criteria and combinational equations given by various researchers were taken into consideration. Statistical analysis of the anthropometric data collected was done and relevant statistical parameters are estimated using SPSS software. Using these parameters in the combinational equations, the match limits for different desk dimensions are computed. The existing classroom furniture dimensions were compared with these match criteria. The results from the present study show that there is substantial mismatch between the existing classroom furniture and the anthropometric measurements of the students.

Keywords: Anthropometry, Classroom Furniture, Ergonomic design.

I. INTRODUCTION

Many researchers have focused attention on ergonomics in work environments in past few decades. One main concern is that ergonomic solution, product, or posture reduces the potential harm to a user when performing a certain task & simultaneously increases productivity, safety and comfort [1]. Although school environment represents the 'work' environment for billions of children, it has not attracted the proper attention from ergonomists [2]. Large number of studies worldwide reveal that there exists a clear mismatch between anthropometrics characteristics and the dimensions of classroom furniture [2-8].This mismatch might affect the learning process, even during the most stimulating and interesting lessons (Hira, 1980) and can produce some musculoskeletal disorders, such as low back pain and neck-shoulder pain (Grimmer & Williams, 2004).Uncomfortable postures could be painful due to the prolonged periods children spend at school. Moreover, it is possible that children may maintain those postural behaviors for the rest of their lives [11].In India also many researchers have identified the problem that classroom furniture is not designed to accommodate the dimensions of the individual user. Use of the ergonomic work station could assist in maintaining a more efficient anatomical alignment of young children when sitting and writing [12].

From all these papers it is the established fact that ergonomic design of school furniture needs more attention. Many authors have tried to establish equations that correlate classroom furniture dimensions to children's anthropometry. Anthropometric measurements of the students become important for this purpose. Children's anthropometric measures vary widely across different age groups, within the same age groups, between genders and between different races [13]. Also, it is mentioned that anthropometric data obtained for a certain region will change within the time in terms of changing socio-economic conditions and therefore, updating of anthropometric measurements made in the studies before at every five years is necessary [14].

The purpose of the present study is to evaluate the classroom furniture in Solapur region in Maharashtra State of India, from the ergonomic point of view and to determine the mismatch between the anthropometric measures and the dimensions of the furniture.

II. MATERIALS AND METHODS

The survey was planned systematically taking into consideration all standard norms. The survey was limited to Solapur city.

A. *Subjects*

Students from 3 schools located in different locations of the Solapur city were identified. Care was taken to see that the 3 schools cover students from different socioeconomic strata of the society in Solapur. Students from the age group of 10 -16 years, studying in 5th to 10th standards are involved. Necessary permissions from the Education officer, School authorities, parents and students are taken before the measurements. 10 students from each division of the different divisions of each standard are randomly selected. Three schools A, B and C were having 2 to 4 divisions of each standard i.e. from 5th to 10th.

B. *Method and equipment used for Measurement*

The body measurements of each student are carried out using standard anthropometric measurement techniques [15]. The consents of the students were obtained before the commencement of the measurements. All anthropometric measures are taken with the subjects wearing regular school uniform and without shoes. The measurements were taken on a chair placed on level floor in one of the

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classrooms in each of the selected institutions. Students were asked to sit erect with upper and lower legs at 90 degrees to each other. Measurements are taken on the working day for around 30 days with the assistance of two teams each consisting of two persons, one for taking measurement and another for data- recording, in the month of October and November in year 2015. To ensure accuracy of recorded data, the persons were given training of using the anthrop meter and other measuring devices in the laboratory and trial runs were conducted. The measurements during the trial runs were checked for consistency and accuracy.

Measuring Equipment consists of anthropometer, measuring tape, steel scale, adjustable chair and a platform for measurement of foot length and a weighing scale for measurement of weight. Body dimensions are measured to the accuracy of 1mm.

Apart from the anthropometric data, geometry of the classroom furniture in these schools is also studied and relevant dimensions are measured. Furniture in all the three schools was of similar design i.e. combined desk bench unit which is common practice in Solapur region. Two sizes of the furniture are found in all the schools, smaller one for grades from 5th to 7th and larger one for standards 8th to 10th. All the relevant dimensions of these desk bench units are measured with steel measuring tape and steel rule to the accuracy of 1mm.

C. Measurements:

Two types of measurements were done viz. Anthropometric data of the students and dimensions of the classroom furniture. Eleven anthropometric parameters and around 8 desk dimensions are measured as described below.

*a. Anthropometric measures:*Following body dimensions are measured.

- Stature (S): Standing height of subject from floor to top of head.
- Elbow Height Sitting (EHS): Distance between lower point of elbow and seat top surface.
- Elbow Height Floor (EHF): Vertical distance between lower point of elbow and floor.
- Popliteal Height (PH): Height of posterior surface of knee from floor knee flexion 90 degrees.
- Sitting Shoulder Height (SShH): Height of shoulder from seat top surface.
- Shoulder Breadth (bi deltoid) (ShB): Horizontal distance between two shoulders.
- Sitting Elbow to Elbow width (SEBW): Horizontal distance between two elbows in sitting and writing position.
- Hip Width (HW): Horizontal distance between two exterior points of hip, subject sitting.
- Buttock-Popliteal Length (BPL): The horizontal distance from the most posterior aspect of the right buttock to the posterior surface of the right knee, subject sitting.
- Thigh Thickness (TT): The vertical distance between the highest points of a thigh from seat top surface.
- Frontal Reach (FR): It is the entire hand length from shoulder to elbow and elbow to fingertip.

b. Desk Dimensions

On the basis of literature survey and considering ergonomic requirements following dimensions of the desk are finalized for the study. Accordingly, measurements of the existing classroom furniture are carried out. It was found that 2 sizes of the desk bench unit are available in all the 3 schools. It is further noted down that the furniture is local made and thedimensions of the furniture from different schools show little variations.

The terms related to desk dimensions and their explanation are referred to from the research paper [16] are described below.

- Seat Height (SH): measured as the vertical distance from the floor to the middle point of the front edge of the seat.
- Seat Depth (SD): measured as the distance from the back to the front of the sitting surface.
- Seat width (SW) / Desk Width (DW): measured as the horizontal distance between the lateral edges of the seat / desk. In case of combined desk bench unit both dimensions are almost same.
- Desk Height (DH): the vertical distance from the top of the front edge of the seat to the top of front edge of the desk.
- Seat to Desk Clearance Vertical (SDC) / Underneath Desk Height: the vertical distance from the top of the front edge of the seat to the lowest structure point below the desk top surface.
- Upper Edge Backrest Height (UEBH): It is the vertical distance between upper edge of backrest and seat.
- Desk Depth (DD): the distance from the back to the front of the top surface of the desk.
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III. THEORY / CALCULATIONS

The equations used for the analysis are compiled from the literature survey. These empirical equations are those which are agreed by most of the researchers. Data analysis was done using modern scientific tools.

A. Equations Relating Anthropometric Parameters and classroom Furniture Dimensions

For ergonomic design of classroom furniture one requires simultaneous consideration of anatomical and ergonomic principles along with financial aspects. Different combinational equations developed by various authors using theoretical and practical ergonomic principles were summarized by the authors [15] in their earlier paper. These equations which correlate the desk dimensions and relevant anthropometric parameters are then used to define the match criteria for the existing desk dimensions. Thesummary of all selected equations for the important relevant dimensions of the desk bench unit are illustrated in the following table I. The classroom furniture used in the school under study consists of combined seat and desk unit designed for sitting of two students. Accordingly, some of the equations in the following table I are modified for accommodating two students.

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Table I : Summary of Equations Selected for Ergonomic Evaluation of Classroom furniture

Sr. No.	Desk Dimension	Relevant Anthropometric Parameter	Equation applicable	Maximum Acceptable Limit	Minimum Acceptable limit
1	SH	PH	(PH+2.5) cos 30º ≤ SH ≤ (PH+2.5) cos 5º	(PH+2.5) cos 5º	(PH+2.5) cos 30º
2	SD	BPL	0.80 BPL < SD < 0.99 BPL.	0.99 BPL	0.8 BPL
3	SW	HB	2HB < SW < 2.6 HB.	2.6 HB	2 HB
4	DW	SEBW	DW > 2 x SEBW.	-	2 SEBW
5	DH	EFH & ShH	DH=0.8517 EFH + 0.1483 ShH; DH =EFH	EFH	0.8517 EFH + 0.1483 ShH
6	SDC	TT	SDC > TT+2	-	TT+2
7	UEBH	ShH	0.6 ShH ≤ BH ≤ 0.8 ShH.	0.8 ShH	0.6 ShH
8	DD	FR	DD = 1.1 FR	1.1 FR	

B. Data Analysis and calculations

Two types of data, one related with student's anthropometric parameters and another related with dimensions of existing classroom furniture are collected from the three different schools in Solapur city.

1) Analysis of Anthropometric data:

This data is analyzed using soft wares SPSS 16 version and MS Excel. Descriptive statistics computed the values of mean, standard deviation, range of dispersion etc. for various body dimensions and for different age groups. This analysis was done with confidence interval of 95% of mean. Tables II-IV present data of the descriptive statistics related with the anthropometric variables classified as per age and sex. Table II provides the data regarding stature, Popliteal Height (PH), and Buttock Popliteal Length (BPL). Of the students. Table III depicts the data related to Elbow Height Sitting (EHS), Shoulder Height Sitting (ShH) and Seating Elbow Width in Writing position (SEBW). While Table IV illustrates the data regarding Thigh Thickness (TT) and Forward or Frontal Reach (FR).

TABLE II: Anthropometric Data of Students - Age, Sex and Standard wise Parameters: Stature, PH, BP

STD	AGE	NO. OF SAMPLES		STATURE				PH				BPL			
				GIRLS		BOYS		GIRLS		BOYS		GIRLS		BOYS	
		F	M	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
V	10-11	90	90	1384	88.48	1403	64.17	371.09	30.68	370.97	26.11	386.44	40.51	383.16	29.73
VI	11-12	90	90	1449	82.10	1432.9	76.50	375.72	21.01	378.21	28.23	419.49	36.93	402.39	41.52
VII	12-13	91	90	1488	84.44	1498	100.87	381.71	22.94	379.42	26.14	439.63	33.32	418.64	37.26
VIII	13-14	89	90	1549	68.19	1579	106.10	389.93	20.99	397.36	33.82	451.39	30.44	441.11	36.34
IX	14-15	80	70	1556	60.48	1626	117.83	394.70	20.67	408.6	33.98	457.51	30.16	454.94	35.80
X	15-16	32	80	1566	33.44	1680	96.37	395.56	16.88	421	29.35	465.31	16.88	459.26	41.02

TABLE III: Anthropometric Data of Students - Age, Sex and Standard wise Parameters: EHS, ShH, SEBW

STD	AGE	NO. OF SAMPLES		EHS				ShH				SEBW			
				GIRLS		BOYS		GIRLS		BOYS		GIRLS		BOYS	
		F	M	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
V	10-11	90	90	202.17	33.91	175.39	24.34	451.78	44.01	450.84	29.73	557.07	61.71	573	52.98
VI	11-12	90	90	205.16	30.61	176.13	26.44	472.79	34.73	456.84	35.37	593.79	43.43	587.37	45.80
VII	12-13	91	90	208.46	30.12	182.4	27.34	500.66	39.46	475.17	49.39	625.94	55.60	612.78	64.98
VIII	13-14	89	90	211.75	29.00	183.17	27.99	524.88	30.36	493.92	44.30	635.84	47.53	642.02	63.34
IX	14-15	80	70	220.64	30.04	192.20	33.74	525.25	33.44	514.67	51.97	638.89	40.50	673.99	51.97
X	15-16	32	80	224.62	30.81	196.11	24.90	537.69	33.44	552.52	41.65	648.20	33.70	714.56	79.04

TABLE IV: Anthropometric Data of Students - Age, Sex and Standard wise Parameters: TT, FR,

STD	AGE	NO. OF SAMPLES		TT				FR			
				GIRLS		BOYS		GIRLS		BOYS	
		F	M	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
V	10-11	90	90	86.51	25.55	87.46	15.06	349.99	32.79	368.51	24.84
VI	11-12	90	90	91.74	24.88	87.51	16.70	370.60	24.32	374.74	29.19
VII	12-13	91	90	104.2	23.03	92.40	20.09	383.58	29.01	393.52	37.05
VIII	13-14	89	90	106.09	23.96	99.50	23.34	396.33	31.15	413.31	33.23
IX	14-15	80	70	108	30.49	104.26	24.12	398.25	21.98	425.81	39.88
X	15-16	32	80	118	26.91	112.41	21.26	404.38	27.77	443.48	36.01

C. Classroom Furniture:

Another data is related with the geometry of the classroom furniture. It is revealed from the literature survey that various models of classroom furniture exist in the different countries in the world. Mainly two types of designs are widely used. One design consists of two separate units, one used for sitting purpose, generally called as Bench or Chair and another one is used for writing or reading purpose known as Desk or Table. Other design combines the two units one used for seating and another for writing, in one combined unit. It is observed that the combined design unit is more widely used in India. [16],[17],[18],[19]. In the schools where study is done, the same combined desk bench unit is used. It is further revealed that in the combined unit design, again two sitter models are more common. However in one school, single combined desk is also used for standards VIII-X.

It was revealed that there exist two sizes of the furniture. One, specified as Size I, is smaller of the two and is used for the students studying in standards V[th] to VIIth and another size is being used for students from standards VIII – X, specified as Size II. Data of seven relevant dimensions is illustrated in the Table V, which are being evaluated in the present study.

Table V: Desk dimensions according to size from three Schools.

Sr. No.	Desk Dimensions	Size I – Schools			Size II – Schools		
		A	B	C	A	B	C
1	SH	467	410	390	468	465	465
2	SD	255	260	250	258	275	257
3	SW / DW	934	830	747	530	910	805
4	DH	739	640	630	750	705	715
5	UEBH	338	345	330	312	320	305
6	DD	347	300	323	395	322	323
7	SDC	254	212	77	92	120	115

Note: All dimensions are in mm.

D. Mismatch Analysis:

Equations relating the desk dimensions and anthropometric parameters from Table I are applied to each and every desk dimension. The maximum and minimum acceptable limits of the particular anthropometric parameter corresponding to that desk dimension are computed. The match criterion was defined for those students whose anthropometric dimensions lie within the limits. Mismatch found is of two types, one, which are smaller than the minimum acceptable limits (minAL) and another which are larger than the maximum acceptable limits (maxAL). These limits are compared to dimensions of each and every student to estimate the match and mismatch frequencies. Further, the exact deviations from the acceptable limits were also calculated for each student.

The evaluation of match was done for allocation of the desks as per the existing situation (Situation 1), i.e. size I for standards V-VII and size II for standards VIII-X, again

for each school separately. The evaluation is also done again for each standard wise and gender wise separately. In the second stage, evaluation is carried out considering that both sizes I and II are available to all the students (Situation 2) for studying the scope of further improvement of match with existing furniture.

IV. RESULTS AND DISCUSSION

Findings of the analysis are grouped in two sections, one related to anthropometric data and other related to mismatch between the existing furniture and the anthropometric parameters as follows.

A. Anthropometric data:

It is observed that there are substantial variations in body dimensions among individuals. All the body dimensions increase with age as expected With the increase of age, development of different body systems such as skeletal system, muscular system and other systems occurs which result in increase of anthropometric measures. In case of girls this rise is rapid in the age range of 10-14 years and later on it flattens while in case of boys there is almost constant rise throughout the age range of 10-16 years. In the age range 11-13 years stature values of the girls are almost same or even slightly higher, however in subsequent years stature of boys increase at higher rate and then the stature of boys becomes higher by almost 100-120 mm at the age of 16 years. These results lie in line with other such studies carried out in India by G C Khaspuri et al [17] and IAP Growth charts [20].

In all the schools studied, two sizes of the school furniture are used as discussed earlier which are specified as size I and size II. The age range for these standards works out to be 10-13 years for size I and 13-16 years for size II. It is revealed from the analysis that the variation in the mean body dimensions of boys is around 20 percent from age of 10 to 16 years and is almost equally divide in each group by around 10 percent. However for girls this variation is only 13 percent and the division of variation is unequal in two groups. For size I group this variation is more than 8% while for size II group it is less than 5%. Hence it necessitates separate considerations for the two genders especially in this age range.

It is seen that there is around 10 percent variation in the mean values of almost each of the anthropometric variable in each age group which is significant and it will be difficult to accommodate all students in the same size of furniture. The problem seems to be aggravated further when one considers the variation between minimum and maximum values of the concerned anthropometric parameter. Estimation shows that variation for stature in case of boys is around 400 mm or 30% for each group size I and size II. For girls it is around 420 mm or 33% for size I group while it amounts to around 300 mm or 21% for size II group. It clearly indicates that the existing furniture is inadequate to cover the variation within the group. This fact is further ascertained when we do mismatch analysis

for each furniture dimension and relevant anthropometric parameter which is done in the subsequent section.

B. Classroom Furniture and Mismatch

It was found that in all the three schools studied the furniture is local made. The awareness about the ergonomic design is very less. Economy of price and economy of space seem to be the main considerations in manufacturing the desks. It was also revealed during the discussions with some school authorities that, price or space are not the constraints while buying the furniture, but it was lack of awareness about ergonomic aspects.As discussed earlier, Match equations from Table I are applied to calculate the acceptable limits for each furniture dimension from different school and for each size I and size II.

Likewise limits were calculated for furniture in each school. These limits are applied to the respective anthropometric parameter data, collected from the schools and frequency analysis is done to estimate the percentages of subjects below minimum acceptable limit, within limits and above maximum acceptable limits. These calculations were done sex wise, school wise and size wise. First, analysis is done as per existing situation 1, as described earlier in section 3.3 and then considering situation 2. The entire analysis is compiled together to estimate the overall mismatch in all the three schools taken together, size wise and gender wise.

Tables VI and VII illustrate the frequencies of this overall mismatch for size 1 and size 2 of the different desk dimensions for female and male students respectively. Similarly, Figure I and II present the bar charts showing the distribution of mismatch and match frequencies for the female and male students respectively.

It is observed that for one of the most important dimension – seat height, the mismatch is substantial in existing condition i.e. situation 1. In case of size I, over 68% females have the PH value below AL for the existing SH of the seating bench and only 31% cases lie within limit. For size II, the case is worst, as only around 2% cases match and over 98% girls lie below AL. B. Biswas et al [5], Claudia Parcelles et al [7], have also reported such higher levels of mismatch in their studies.

In situation 2, there is considerable improvement in the match frequencies. The overall match percentage improves from around 16% to over 34%. In case of male candidates also the results are similar. Little over 26% and 16% subjects match the SH for sizes I and II respectively. While over 71% and 83% cases lie below AL in situation 1. In situation 2, again there is substantial improvement in the match cases from the overall 21% to over 35%. In general, it can be said that the SH of existing furniture is substantially higher than the required and as a result the students are not able to get the appropriate support of their feet to balance their weight. This lack of foot support may

increase tissue pressure on the posterior area of the knees [10]. These findings are similar to those obtained by [2].

Seat Depth is another important seat dimension whose proper value provides sufficient support to thighs. It is seen that there is worst situation for this dimension as the existing SD is too less. Neither girls nor boys can get the matching furniture for both the sizes I and II. Hardly 2% girls and 1% boys get the match, while over 98% both boys and girls find that SD is below minimum AL, in situation 1 as well as 2. Too shallow depth observed results into more pressure on lower sitting area of the body.Desk width is one more dimension where again very high almost 100% mismatch is observed in case of both male and female students. Even in situation 2, the improvement is meager up to 4% only. The inadequate desk width causes uncomfortable situation, as there is no enough elbow space when students are writing. As compared to earlier dimensions there is better situation for the desk height, which is one more important dimension. In case of females almost 39% for size I and over 46% for size II match frequencies are found in situation 1. However there is not much improvement in situation 2. For boys however, the situation is not good, as only around 19% and 26% students from size I and size II could get the compatible desk height in situation I. Although there is slight improvement in overall match percentage from around 22% to around 29%, in situation II, the case is still far from satisfactory. It is further revealed that in case of over 40% girls and around 70% boys the DH lies above the maximum AL. It is observed that the higher DH causes discomfort to hands especially while writing. Higher than maxAL desks imply that most children are required to flex their shoulders more than 25 degree and abduct them more than 20 degrees in order to support their elbows on the desk [2], Parcelles).These findings are also in line with the earlier researches by [2], [17], [18], [19].

SDC – Seat to desk clearance is one more dimension which bears upon the sitting comfort of the students. The tables VI and VII indicate that for females the match value is around 68% and 25% for size I and size II. This value improves in situation 2 from overall 47% to 78%. In case of males, the match frequencies are 68% and 34% respectively for size I and II. The overall match value improves to around 90% from 50% in situation 2. The match value for male is slightly higher as compared to the females owing to the fact that thigh thickness of the girls is higher than that of the boys.

Further investigation of desk designs reveals the fact that SDC is lower where bag shelf is provided below the desk top as observed in some of the furniture designs. In such cases mismatch is 100%, it means no enough space to put the knee or thigh underneath the desk, causing discomfort.

Back rest height is matching in almost 87% of the girls in case of size I, however the match drops to around 42% for size II.

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TABLE VI: Mismatch Analysis for Female students showing percentage frequencies

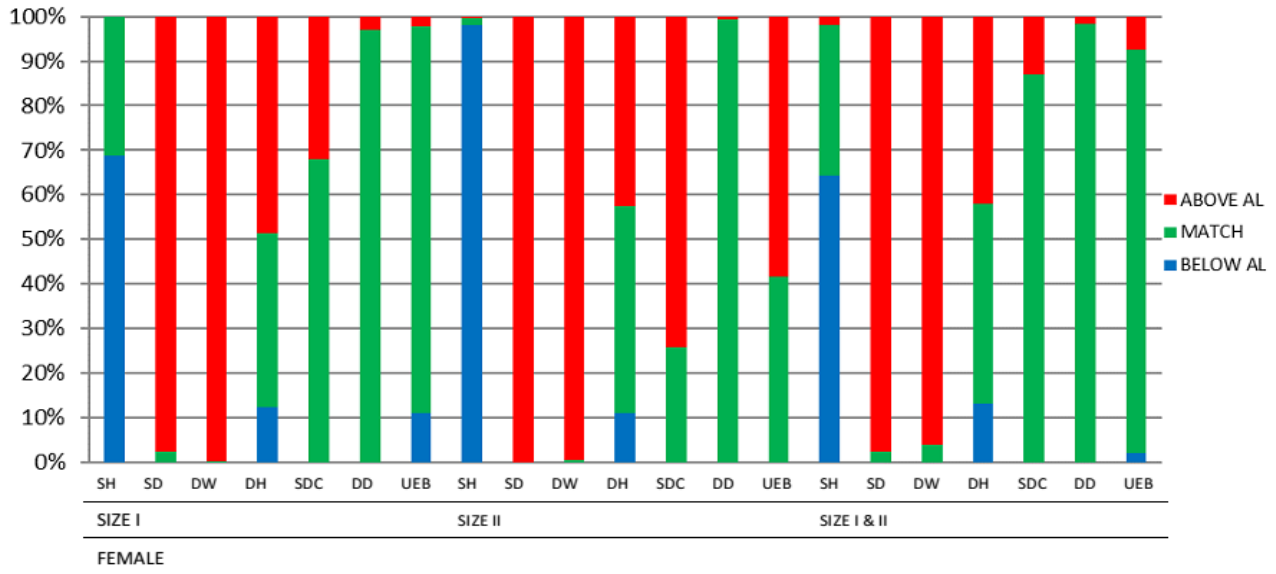| DESK DIMENSION	FEMALE								
	SIZE I			SIZE II			SIZE I AND II		
	ABOVE MAX AL	MATCH	BELOW MIN AL	ABOVE MAX AL	MATCH	BELOW MIN AL	ABOVE MAX AL	MATCH	BELOW MIN AL
SH	68.76	31.24	0	98.03	1.63	0.33	64.17	34.03	1.8
SD	0	2.20	97.8	0	0	100	0	2.17	97.83
DW	0	0.27	99.73	0	0.33	99.67	0	3.87	96.13
DH	48.63	39.03	12.33	42.63	46.33	11.03	42.13	44.76	13.06
SDC	0	67.93	32.06	0	24.96	72.23	0	78.20	11.80
DD	0	96.96	3.03	0	99.33	0.66	0	98.30	1.70
UEBH	10.90	86.96	2.10	0	41.70	58.30	2.03	90.47	7.53

Fig.I : Bar chart showing distribution of frequencies of match and mismatch –Female

TABLE VII. Mismatch Analysis for Male students showing percentage frequencies

| DESK DIMENSION	MALE								
	SIZE I (1-9)			SIZE II (10-18)			SIZE I AND II (19-28)		
	ABOVE MAX AL	MATCH	BELOW MIN AL	ABOVE MAX AL	MATCH	BELOW MIN AL	ABOVE MAX AL	MATCH	BELOW MIN AL
SH	71.40	26.56	2.03	83.30	16.30	0.36	58.5	35.56	5.96
SD	0.37	1.00	98.63	0.37	0	99.63	0.20	1.633	98.17
DW	0	0.266	99.73	0	0.33	99.66	0	3.90	96.06
DH	80.83	18.80	0.37	72.80	25.86	1.33	69.30	28.73	1.97
SDC	0	102.33	32.76	0	34.53	65.46	0	90.10	9.90
DD	0	98.70	1.30	0	98.96	1.03	0	98.83	1.16
UEBH	13.26	85.06	1.67	0.37	53.70	45.93	1.56	86.56	11.86
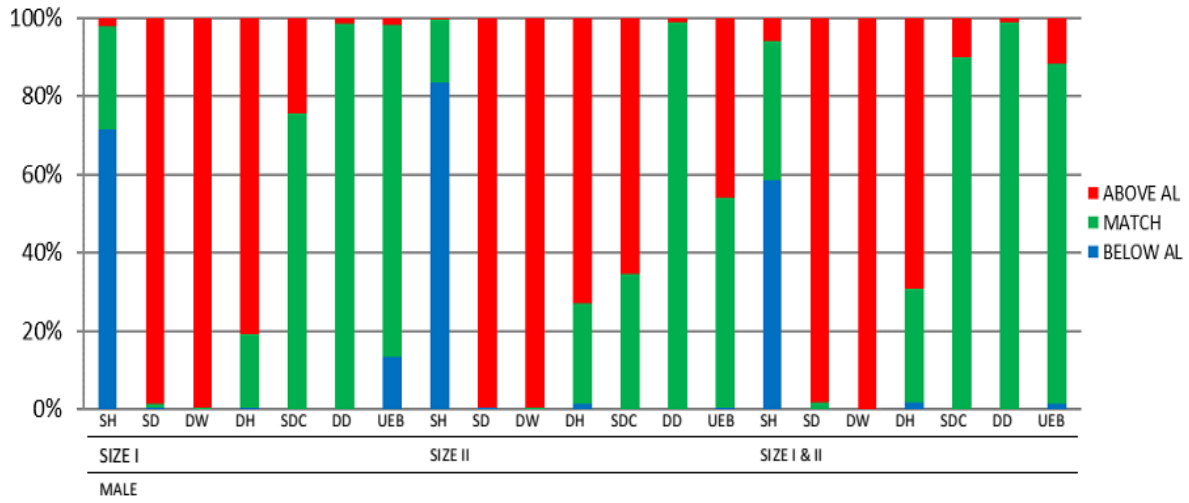
Fig. II: Bar chart showing distribution of frequencies of match and mismatch – Male

Overall match frequencies improve from around 45% to 90%, in situation 2. In case of boys the situation is slightly better. The match frequencies are 85% and 54% for size I and II respectively. In situation 2, the match cases improve in general from around 72% to 87%. The match frequency in case of size II is lower in case of boys as their height is greater than those of girls in that age group. In case of size I mismatch cases lie below AL, it means shoulder heights are lower and the students don't get enough free movement for their shoulder movement. While in case of size II mismatch cases are above max AL, which indicates that backrest heights are lower than required and hence fail to provide proper rest to the backs of the students.

However these back rests don't restrict free movement of shoulders.
Another dimension related to the desk is depth of the top – DD. In this case almost all frequencies i.e. around 98% are lying within AL, it means within the FR of the students. However, authors are of the opinion that appropriate value of the DD also depends upon some other factors such as the dimensions of the note books and books being used and requirement of writing space etc. Hence, further research is necessary.

V. CONCLUSION

While summarizing the findings it can be stated that there is substantial mismatch between the anthropometry of the students and existing furniture dimensions. Especially for most important dimensions such as seat height and desk height the mismatch is alarming, in the range of 70%. For seat depth, the mismatch is almost nil. In case of desk width also, the mismatch is very high. Although the situation is better for other dimensions such as desk depth, seat to desk clearance, back rest height; there is substantial scope for their improvement. Deviations from the acceptable limits vary with age and gender within the same size of furniture. If the situation is considered that both sizes are available to all age group students then there is significant improvement in the match frequencies in case of some dimensions such as seat height and desk height, the situation is still far from satisfactory. In case of seat depth

however, there is no improvement in situation 2 also. Still, it can be said that the match improves if the allocation of existing furniture is done according to anthropometric measurements of the students.

The variation in the anthropometric parameters suggests that existing two sizes of furniture are inadequate to cover the range of the age group and gender. It necessitates therefore, the more variety of sizes of the furniture. Even for the same age one size furniture may not be sufficient due to variation of the anthropometric parameter as well as difference in the sex. Again the allocation should be done as per the anthropometric measurements. Hence in one class two sizes might have to be provided.

The present study is based on the empirical equations based on the literature. Further research can be done with some experimentation based on more scientific basis. Moreover some more dimensions of the furniture are not discussed here, where much literature is not available. Hence there is scope for more research in this area. Similarly, one more fact is revealed that the anthropometric data differs from time to time and region to region. Hence there is need to conduct anthropometric surveys, frequently in different regions of India.

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