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Research Article

Anthropometric Consideration for Designing Students Desks in Engineering Colleges

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Abstract

The present study is aimed to evaluate the extent of mismatch between different dimensions of students furniture and the respective anthropometric measures of students. For this purpose, 400 engineering students in the age group 18-24 years were randomly selected from engineering colleges in North Karnataka . The dimensions of the students desks available in the classrooms were taken. The class room furniture was evaluated with a defined match criterion given by various researchers. For the evaluation of classroom furniture a match criterion equation was defined. After considering the existing classroom furniture dimensions in each match criterion equation, the anthropometric characteristics of the considered population were compared in order to determine the mismatch between them. The results from the present study show that the college furniture is far from compatible with the anthropometric measurements of the students. there was a significant difference between the desk height and the sum of elbow rest height and popliteal height of the students, seat height and popliteal height, seat width and buttock popliteal length.. Incompatible furniture forced the students to adopt unnatural postures (lateral bend, forward bend, twisting, etc.) in the classroom for long periods, which imposes physical and mental strain on the students. It is recommended to develop an anthropometric database of students and on the basis of it, at the time of renewal of furniture, take into consideration this information either to gain adjustable furniture or possibly acquire, in size, three types of desks, large, medium and small so that students have the options and find the most suited to their anthropometry.

Key words: *Anthropometry, College Furniture, Students, Posture*

1. Introduction

Ergonomics in the design of workplace and work environments has gained high attention from researchers over the last few decades. Though school environment represents the ‘‘work’’ environment for billions of students, it has not attracted the proper attention from ergonomists (Gouvali 2006). School furniture is one of the important physical facilities provided in a classroom environment where the students spend most of their time. The design of workplace for students should ensure body comfort for effective learning process. The functional utility of the student's classroom furniture is a result of its physical design in relationship to the physical structure and biomechanics of human body.

Anthropometric data is a collection of the dimensions of the human body and are useful for apparel sizing, forensics, physical anthropology and ergonomic design of the workplace (Ismaila 2009). Ergonomics and anthropometry have been used to develop furniture which includes office desks and chairs by incorporating adjustability in order to accommodate a wider range of people and population. This is aimed to suit not only a range of postures but a range of users. It has been noted that anthropometric data vary considerably for individuals within a family or a nation and between nations. Reliable anthropometric data for a target population were necessary when designing for that population otherwise the product may not be suitable for the user. The use of anthropometry in design may improve the well-being, health, comfort, and safety of the user of the product (Pheasant, 1998; Barroso et al., 2005). The use of anthropometric data in the design of school desks and tables in almost all modern developed countries has been acknowledged (Parcells et al., 1999).

The comfort, physical health, well-being, and performance of people can be increased by designing equipment, goods, furniture, and other devices according to the needs of the human body. One of the conditions to support productivity is to ensure that the work spaces and equipment that people use conform to the anthropometric and biomechanical characteristics of the users.(Metin Tunay 2008). The use of poorly designed furniture, especially school desks and tables, that fails to account for

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the anthropometric characteristics of its users has a negative influence on human health.(Metin Tunay 2008). (Pheasant 1986) stated that the purpose of seating furniture is to provide stable body support in a posture that is comfortable over a period of time, physiologically satisfactory and is appropriate to the task or activity being considered. Appropriate anthropometrical requirements should also be considered for sitting, for seat and work surface dimensions, legroom and clearances for getting in and out (Chakrabarti 1997).

To obtain fitness between man-machine components, the maximum number of user population should use a workplace. It strives to accommodate 95 percent of the user population, in general. The dimensions of the small people establish the reach dimensions, i.e., If the shorter people can reach the objects located on higher shelves, virtually everyone else can also do the job. On the other hand, when the taller people can fit in a confined area, like aisle, tunnel area, emergency exit, all others can also be accommodated.(Adekunle Ibrahim Musaa).

As anthropometric dimensions vary among nations and ethnic groups and change over time as populations and their environmental conditions change, it is necessary that the school furniture should also be designed to fit the requirements of students. Therefore, the school furniture should be made on the basis of anthropometric dimensions of the users.

2. Literature Survey

Many researchers have proposed numerous methodologies for various furniture designs in the past. Until recently, the design of student desks has received little or no interest. The focus of ergonomic design of furniture has been traditionally based on the design of work furniture based on the anthropometry and biomechanics of the human body. The anthropometric measurements that are necessary to determine the dimensions of school furniture that will enable students to maintain correct sitting posture are popliteal height, knee height, buttock to popliteal length and elbow height (Parcells et al.,1999; Panagiotopoulou et al., 2004).

The main anthropometric dimension and specification used in student furniture design is Popliteal height which is to determine appropriate seat height . In designing a chair to suit a population, the popliteal height is used to ensure that members of the population are able to sit with their feet supported on the floor, and without undue pressure behind the knees. Likewise, comparing the popliteal height of an individual to the seat height of the available chairs can assist in selecting the most suitable size for that individual.

According to Parcells et al. (1999), school children are at special risk for negative effects from badly designed and ill-fitting furniture, due to prolonged periods of sitting during school. According to Grimes and Legg (2004), the combination of bad posture and poor seating coupled with long periods of immobility can lead to the development of lower back pain. Further they have stated that with expectations and emphasis (in some sectors) on greater educational achievements, the duration of sitting is likely to increase. An uncomfortable sitting posture can lead to health related consequences, and also student’s learning interest, even during the most stimulating and interesting lessons (Hira, 1980).

(Chaffin et al. 2006) emphasized the need for the feet to be firmly rested on the floor or foot support in order to prevent the thighs from supporting the weight of the lower leg. The literature review indicates that providing an optimal design solution with sufficient comfort is an extremely difficult task when a fixed-type chair is used. According to (Straker et al., 2006) workstations with adjustable seats are favored, since people differ in size and postural preference. Adjustable chairs are preferred for school students or adults, to promote health and comfort in sitting. Further he stated that seat height adjustability is the most important element of a workstation and is used the most often. Robinette (2006) urged that a product’s ultimate success depends on how the variations in shape and size of the user population will be accommodated. Toomingas and Gavhed (2008) conducted a study of call center operators, and concluded that optimal adjustment of the chair may contribute to less frequent neck/scapulae and back pain .

Adjustability of school furniture is an important feature in ensuring equal educational opportunities, increased comfort, and decreased incidence of musculoskeletal symptoms. According to [10] stated that a mismatch between thigh length and seat depth is significantly related to general sitting discomfort, and a mismatch in seated elbow height and desk height is significantly related to reported neck and shoulder pain. Hira (1980) after investigating fixed-type university chairs, suggested that the seats should be adjustable. (Khanam et al. 2006) evaluated fixed-type university furniture, including a mounted desktop chair, and concluded that students preferred the furniture height to be adjustable

Many authors have tried to establish theoretical recommendations for the principles that relate school furniture design to children’s anthropometry, and some have also attempted to define the ‘‘appropriate’’ dimensions for school furniture based on anthropometric measurements.

Without proper design, sitting will require greater muscular force and control to maintain stability and equilibrium. This, in turn, results in greater fatigue and discomfort and is likely to lead to poor postural habits as well as neck or back complaints. Instead, a one-size-fits-all philosophy has been adopted in the industry, because such furniture is less costly to manufacture and easier to sell at a lower price, and lessens the inventory problems for manufacturers and schools. Existing designs have basically been unaltered for years.

Therefore a need is felt where the ergonomist’s have to treat the issue of furniture design for students as a necessity and educational institutes/universities should treat the selection of right kind of furniture as social responsibility towards the student community. The present study focuses on collecting the anthropometry data of students in engineering colleges and comparing it with the existing desks to find out the mismatch between the body dimensions and desk dimensions. Further a questionnaire survey was conducted to find out the student preferences about the desks and suitable suggestions are made to incorporate students anthropometry dimensions and students preferences in future design of student desks.

3. Methodology

The present study was focused on the Engineering colleges of North Karnataka region to explore the types of classroom furniture used in different colleges and their suitability with the user populations A total of 400 students consisting of equal numbers of male and female students were selected randomly, between 18-24 years of age, studying in different semesters and branch of engineering.

3.1 Anthropometry Measurements

Different anthropometric measures of the students were taken by adopting proper definitions and standard measuring techniques (Chakrabarti, 1997). An anthropometer was used for measuring the body dimensions. Accuracy and repeatability of measurement was achieved by practice prior to the data collection sessions. The data recorded for a subject was the mean of three trials. All subjects were wearing light clothes and were bare footed during measurements. During measuring body dimensions under sitting condition, the subjects were asked to sit in such a way that the upper leg and lower leg remained at right angle to each other. The following anthropometric dimensions were taken for this study based on the literature survey and shown in fig. 1 and the values of dimensions measured is shown in Table 1.

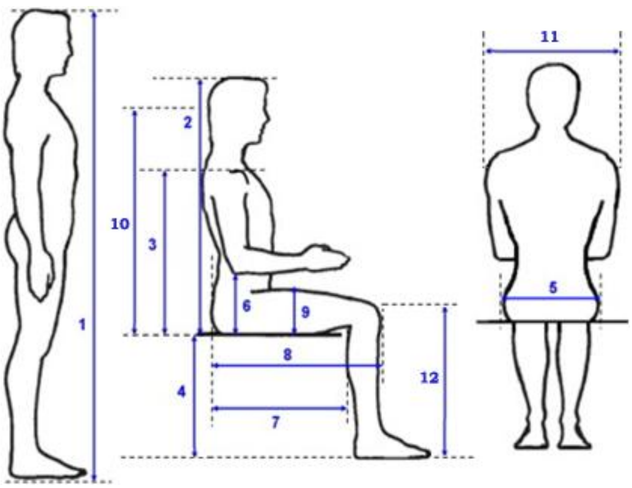


Fig 1 Anthropometry dimensions measured

1. Stature: Top of the head, standing in erect stretched posture. The vertical distance from the floor to the vertex (i.e. the crown of the head)
2. Sitting height: Top of the head sitting in a normal relaxed posture.
3. Sitting mid shoulder height: Height of upper most point on the middle level of the shoulder.
4. Popliteal height: Height of the underside of the thigh immediately behind the knee.
5. Hip breadth: Maximum horizontal distance across the hips.
6. Elbow rest height: Distance between seat and lower most part of the elbow
7. Buttock popliteal length: Horizontal distance from the most posterior point on the uncompressed buttocks to the back of the lower leg at the knee
8. Buttock knee length: Horizontal distance from the most posterior point on the uncompressed buttocks to most anterior point on the knee
9.Thigh clearance: The vertical distance from the seat surface to the maximum bulge on the anterior surface of the thigh was measured with a shortened anthropometer.
10.Sitting eye height: Height of inner corner of the eye sitting in normal relaxed posture.
11.Shoulder breadth: Maximum horizontal distance across the shoulders,
12. Knee height: Height of uppermost point on the knee.

Table 1 Anthropometric measures of the body dimensions of the students

R.no.	Parameters	Min	Max	Percentiles			Mean	± SD
				5^{th}	50^{th}	95^{th}		
1	Stature	141	182	147	161	172	160	8.78
2	Sitting height	61	91	67	79	90	79	7.12
3	Shoulder height	38	73	46	54	67	55	7.44
4	Popliteal height	30	64	34	40	45	41	3.2
5	Hip breadth	26	43	30	34	38	34	2.76
6	Elbow rest height	47	100	53	62	73	64	6.26
7	Buttock popliteal length	21	53	37	44	49	44	3.83
8	Buttock knee length	32	65	41	50	64	50	6.82
9	Thigh clearence	11	18	11.5	15	18	14.5	1.7
10	Sitting eye height	57	80	55	68	79	67	8.2
11	Shoulder breadth	26	52	31	40	48	40	5.25
12	Knee height	32	95	40	47	54	47	4.88
13	Weight	35	84	40	53	72	56	11.5

3.2 Percentiles

In designing for a known individual, one's own body dimensions may be measured and used. However, for mass application the percentile values of a study population are usually required. A 95 th percentile value of a body dimension (e.g., body height) would indicate that 95% of the study population have the same or less body height, and only the remaining 5% of the population have greater heights. The 50 th percentile value represents closely the average, which divides the whole study population into two equal halves. As a matter of fact, no such person really exists, having all the body dimensions of 95th or 50th or 5th percentiles. Therefore, in design application, different percentile values of different dimensions may be necessary even on a simple design solution. Based on task requirement, appropriate percentile selection of body dimensions is required.

Lower percentile values are considered for accommodating the maximum number of people having higher values, where easy reach is the concern. Higher percentile values are considered where the maximum number of population having lower values cannot reach the level, as required in ensuring safety and ease of operation (Nag, 1996). In the present investigation, various percentile values (5th, 50th and 95th) of different anthropometric dimensions of the students are computed for the purpose of designing students desks.

The anthropometric dimensions measured were analyzed using standard statistical package SPSS. The normal distribution and histogram were obtained for some of the important parameters and are plotted as shown in fig. 2.

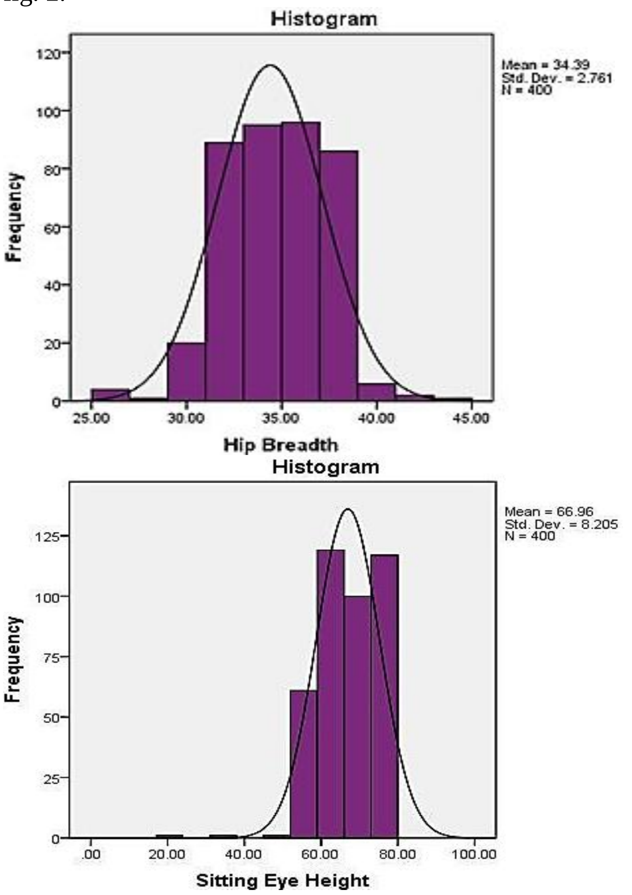
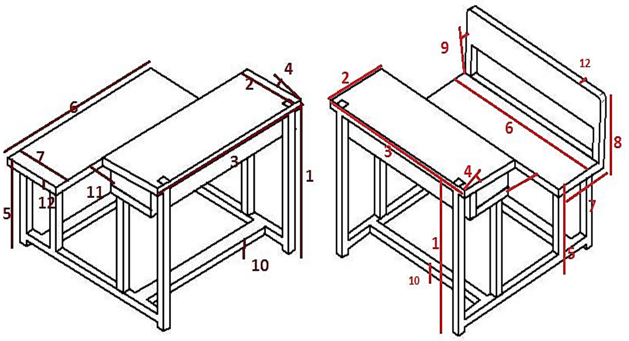


Fig 2 Normal distribution graphs of Hip Breadth and Sitting Eye Height

3.3 The Students Desks

The available student desks from 4 different engineering institutions were selected for the study. The desk dimensions (Table 2) were measured for analysis and comparison with the student anthropometric characteristics. The colleges had different types of desks, some of the desks were without back support, and some were having back rest support. Most of the desks were two seater with an exception. It was observed that the variations in desks were due to the fact that these were procured from various manufacturers at different point of time. There was not a single supplier and while purchasing the desks the college authorities did not give any specifications or designs. Whatever design and specifications supplied by the manufacturers were accepted. Hence it is the basic reason for the mismatch of the furniture. The relevant anthropometric dimensions and their significance in the design of desk are shown in Table 3.



(a) (b)

1. Desk Height 2.Desk Depth 3.Desk Length
4. Desk Slope 5.Bench Height 6.BenchLength
7. Bench Depth 8.Backrest Height 9.Backrest Slope
10. Footrest Height 11.Distance b/w Desk and Bench

Fig 3 Existing desks in colleges (a) without back support (b) with back support

Table 2 Dimensions of the desks in classrooms

Dimensions Of Student Desks of Different Models (in cm)								
S.No.	**Furniture Part**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
1	Desk Height	75	76	79	83	84	80	85
2	Desk Depth	45	45	37	41	34	40	40
3	Desk Length	91	91	92	93	113	94	83
4	Desk Slope (degrees)	-	10	8	8	6	6	4
5	Bench Height	47	46	51	50	40	50	45
6	Bench Length	91	91	92	93	113	94	84
7	Bench Depth	31	32	31	33	26	30	30
8	Backrest Height	-	48	48	-	-	40	30
9	Backrest Slope (degrees)	-	100	94	-	-	-	95
10	Footrest Height	11	7	15	7	4	15	2
11	Dist B/W Desk & Bench	22	32	33	30	32	25	15
12	Thickness	2.5	2.25	2	2.5	2	2	1.5

4. Results and Discussion

The finding from the measurement of the student body dimensions and the classroom desks used are that a considerable mismatch occurs between the furniture and the users. A mismatch can be defined as incompatibility between the dimensions of the student's body and the furniture dimension. The percentage and number of the students where the body match or mismatch with the furniture is calculated based on the rules adapted from (Parcells et al., 1999). Many researchers have given the mismatch rules, and these rules are followed here in order to determine the mismatch between different body dimensions and its corresponding design parameters. The following equations which are based on theoretical and practical ergonomics principles were utilized to define the minimum and maximum limits between which each dimension is considered appropriate. For designing a student desk to fit the user population it is recommended that the following mismatches should be taken care by the designers and necessary changes incorporated in the design.

4.1 Equations relating body dimensions to student furniture dimensions

4.1.1.Popliteal height and seat height mismatch

A mismatch is defined when the seat height was either >95% or <88% of the popliteal height (Parcells et al. 1999) The seat height (SH) should be adapted relatively to popliteal height (PH) thus allowing knees to be flexed so that the lower legs form a maximum of 30^o angle relative to the vertical axis. The equation below declares that seat height should be lower than popliteal height so that (1) the lower leg constitutes a 5–30 angle relative to the vertical and (2) the shin-thigh angle is between 95 and 120. In our case, a 2 cm correction for shoe height was added to popliteal height (Sanders and McCormick, 1993)

$$(PH+2) \cos 30^o \leq SH \leq (PH+2) \cos 5^o$$

The height of the seat should match the popliteal distance and length of the footrest. To facilitate comfort for short and tall persons the adjustable height in seat should be preferred. Khanam 2006, recommended 50th percentile for normal individual and adjustment provision of 5th percentile value for short persons and 95th percentile value for tall persons in the design of seat height.

4.1.2.Buttock-popliteal length and seat depth mismatch

Many researchers have reported that seat depth (SD) should be designed for the fifth percentile of buttock popliteal length (BPL) distribution, including even the shorter users (Helander, 1997; Khalid Al Saleh 2011, Sanders and McCormick, 1993). According to M.G. Mohamed Thariq 2010, seat depth should be at least 5 cm shorter than buttock popliteal length. Parcells et al. (1999) have stated as mismatch the case when the seat depth was ≤ 80% or ≥ 95% of buttock popliteal length. Since the present study represented an initial attempt to examine the potential mismatch, the upper limit was further increased to 99% of popliteal-buttock length and the equation was modified as follows:

$$0.80\ BPL \leq SD \leq 0.99\ BPL$$

The effective seat length suggested was that it should be 1/5th less than the buttock - popliteal length, with 5 degrees back slope from 3/4th of the seat depth. The front edge of the seat should have a curvature, preferably water fall seat of 3 degrees slope. The recommended dimension of 400 mm was considered.

4.1.3.Seat width (SW)

Seat width should be large enough to accommodate even users with the largest hip breadth (HB) . The modified equation proposes that seat width should be at least 10% (to accommodate hip breadth) and at the most 30% larger than hip breadth (for space economy).

$$1.1\ HB \leq SW \leq 1.3\ HB$$

The hip dimensions were used for a static fit work. The relaxed mid- thigh-to- thigh distance, the 75th percentile value, that would accommodate the 95th percentile of the hip breadth was recommended by Chakrabarti, 1997, he stated that the seat width should never be less than 400 mm (Khanam 2006)

4.1.4.Backrest height (B)

Backrest is considered appropriate when it facilitates mobility of the trunk and arms. The equation recommends keeping the backrest at most on the upper edge of the scapula (60–80% of shoulder height (SH)).

$$0.60\ SH \leq BH \leq 0.80\ SH$$

As suggested by Chakrabarti (1997)the height of the lower backrest from the seat surface should be in tune with the 5th percentile value of the lower lumbar height so that all persons having a greater height can get support, and the 95th percentile of upper lumbar height The backrest angle preferred was 100 degrees since all the classroom activities call for alert sitting posture.

4.1.5. Desk height (D)

Many researchers have considered elbow rest height as the major criterion for desk height (Dul and Weerdmeester, 1998; Sanders and McCormick, 1993) based on the fact that there is a significant reduction in the load on the spine when arms can be supported on the desk. According to (Pheasant 1991) the desk should be 3–5 cm higher than the elbow. Parcells et al. (1999) suggested that desk height should be adjusted to elbow floor height, so that it would be minimum when shoulders are not flexed or abducted, and maximal when shoulders are at 25^o flexion and 20^o abduction (elbow rest height x 0.8517+shoulder height x 0.1483). The equation has further been modified based on the fact that elbow-floor height is the sum of elbow rest height and seat height

$$EH+[(PH+2) \cos 30^o] \leq D \leq [(PH+2) \cos 5^o] + (EH\ 0.8517) + (SH\ 0.1483)$$

4.1.6. Desk Depth

According to Phesant, S(1986) the individual space requirement for work table, the minimum arm reach should be considered which is taken as the 50th percentile minimum arm reach value.

4.1.7 Desk Width

Phesant, S (1986) has recommended relaxed elbow to elbow width at 50th percentile value along with clearance for a work table should be considered.

4.1.8. Desk Top Angle

The inclined angle of the desk top should be 10 degrees as suggested by de Wall et al. (1991)

4.1.9. Footrest Angle

The footrest angle was recommended as the 15 - 30 degrees by Chakrabarti (1997) and it was taken into consideration.

4.1.10. Underneath desk height (UD)

UD should be enough so that there is space between the knees and the underneath surface of the desk (Dul and Weerdmeester, 1998; Helander, 1997; Sanders and McCormick, 1993). Parcells et al. (1999) proposed that the desk clearance should be at least 2 cm, while other researchers have proposed at least 5 cm of clearance. According to Helander (1997), this space should also allow for knee crossing. In accordance with the above, the equation considered as appropriate the case that underneath desk height was at least 2 cm higher than knee height (but not higher than desk height plus its thickness minus 4 cm)

$$\mathbf{(KH + 2) + 2 \leq UTH \leq (PH + 2) \cos 5^o + 0.85\, EH + 0.14\, SH - 4}$$

Conclusion

The results from the present study show that the college furniture is far from compatible with the anthropometric measurements of the students. This furniture is designed by local manufacturers without proper consideration of the anthropometry dimension requirements of the students. The studies of different researchers showed that there was a significant difference between the desk height and the sum of elbow rest height and popliteal height of the students. Such mismatch may induce physical problems in those using the furniture.

Students usually attend lectures in classrooms class for a long period of time (about 4-5 h/day) in a sitting posture with ill designed classroom furniture. Incompatible furniture forced the students to adopt unnatural postures (lateral bend, forward bend, twisting, etc.) in the classroom for long periods, which imposes physical and mental strain on the students. Fatigue may also be caused by sitting for long duration of time in the classroom adopting to improper posture, and may lead to operational uneasiness and musculoskeletal and some physiological disorders among students.

Most of the student desks examined were without backrests. Based on several complaint of body aches and discomfort from the students, a survey was conducted to obtain additional information which could be helpful for the research analysis. The study revealed that designing each component of furniture with care and attention to user's need can result in user friendly design. Opinion of the students and the ergonomists guidelines for evolving good furniture formed the criteria for new furniture designs.

The results obtained show that there is consistent evidence to conclude that the dimensions of the desks used by the Engineering students of the study population present a mismatch with the anthropometric characteristics of students and, considering that in some cases this mismatch is very strong, can be an important factor which influences the academic productivity of the same. It is recommended that in sled desk type of furniture the seat frame and bench frame should be designed to provide adjustment of height for tall and short persons. Leg frames of both seat and desk should have provisions to move the seat frame and the desk frame up and down from 50th percentile height to 5th and 95th percentile value height and tightened by a screw to form into a single unit. Seat frame should be designed to accept the body curves. Backrest support is to be provided at lower lumbar and upper lumbar. Desk design should give due consideration to the minimum arm reach, elbow rest height and arm length. The provision for books should be designed and provided below the desk top.

From the above findings and considering that this is a relatively small sample in relation to the size and diversity of environments within the engineering students study and the large number of institutions ,it is recommended to develop an anthropometric database of students and on the basis of it, at the time of renewal of furniture, take into consideration this information either to gain adjustable furniture or possibly acquire, in size, three types of desks, large, medium and small so that students have the options and find the most suited to their anthropometry

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