SUMMARY AND CONCLUSION
CHAPTER – V

SUMMARY AND CONCLUSIONS

A school is a home away from home for the children, with a purpose to facilitate their learning activity. During their lives, children spend approximately a quarter of the day at school, and 80% of their time sitting down doing their school work. Considering the amount of the time spent at school and specifically while sitting, it is fundamental that school furniture suit the children’s requirements (Savanur et al., 2007) and it should also allow for the changing postures (Yeats, 1997).

Anthropometry and ergonomics have been used to develop new furniture forms which include task or office desks and chairs by incorporating adjustability in order to accommodate a wider range of people and population. This is not only aimed at suiting a range of users but also a range of postures (Leuder and Rice, 2007). Ergonomics aims to design work and environment for people, so that they can work easily, effectively and safely. Ergonomics is needed to maintain consistency in the performance of the worker and reduce the unpredictability of output of work.

One of the most important factors in ergonomics is to provide a well-designed article or a system with proper safety, comfort and the confidence for free use. Through anthropometry, ergonomics collects information about people so that work, machines, tools and environment are fitted to humans (Chakrabarti, 1997). Humans are variable in dimensions, proportions and shape, as in all other characteristics and user-centred design requires an understanding of this variability. It is important to see that the products are designed appropriately to anthropometric dimensions of the humans.

The variability of human beings is great, but it can be accommodated through empirical design. In terms of ergonomics, comfort integrates a sense of well-being with health and safety. Conversely, discomfort could be related to biomechanical factors involving muscular and skeletal system (Zhang et al., 1996). The comfort, physical health, well-being and performance of people can be increased by designing equipment, furniture and other devices according to the needs of the human body.

The classroom is a formal environment for learning. A conducive and comfortable classroom environment motivates the students to perform better and encourage the
learning process. School work requires them to sit for “extended” periods of time (Freudenthal et al., 1991; Knight and Noyes, 1999).

During growth, children undergo many changes that are anatomical, physiological and psychological in nature. Static posture and prolonged sitting in a forward bending position, as students often acquire, puts an extreme physiological strain on the muscles, the ligaments and in particular on the discs (Bendix, 1987; Brunswic, 1984). Correct standing and sitting posture is an important factor for the prevention of musculoskeletal symptoms (Cranz, 2000). Furniture has an important role in the maintenance of good sitting posture. Using furniture that promotes proper posture is more important as sitting habits acquired in childhood that is very difficult to change later in adolescence or adulthood (Yeats, 1997).

Furniture facilitates the functioning of students in a classroom. It should permit space for flexible movements of the body, provide place for all the education activities and must possess adequate storage for their personal belongings used by them, during the school children work in classroom. While all the components of classrooms environment are important, furniture for seating require special attention especially with regard to anthropometric measurements.

Anthropometric measurements are an important factor that should be taken into account in classroom furniture design. Specific measurements, such as popliteal height, knee height, buttock-popliteal length and elbow height are necessary in order to determine school furniture dimensions that enable the correct posture (Knight and Noyes, 1999; Parcells et al., 1999; Miller, 2000). Chaudhary et al., (2004) showed that on an average, the school furniture did not match up with the school children’s anthropometric measures. So most of the time, they had to spent in the classroom sitting for a long duration at a time confining themselves to traditional cumbersome sitting and writing furniture units (Chakrabarti et al., 2004).

Wrongly designed school furniture induces improper posture leading to operational uneasiness and musculoskeletal and some physiological disorders among school children (Chaudhary et al., 2004).

Poor or awkward posture can cause fatigue, strain and eventually pain and may result in structural deformation of the body, with muscle spasm, pain in the back and legs,
decreased lung capacity, poor circulation, kinks in the bowel and many irregularities in the function of the body. The human body is designed to be on the move and the benefits of sitting can only be achieved through good posture and exercise.

During past decade, research in ergonomics has led to heightened interest in the technology of work and furniture design based on the biomechanics of the human body. However, little interest has been shown in the largest workplace of all: the School. Schoolchildren are at special risk for suffering negative effects from badly designed and ill-fitting owing to the prolonged periods spent seated during school.

Therefore, the present study was attempted to investigate the incompatibility between classroom furniture and student’s body dimension if any. The study will give an insight to know about whether the type of classroom furniture used for students is well designed to promote good sitting posture and thus, will help reduce the effects of postural problems, allowing students to sit in ergonomically correct positions.

Also, the present study was attempted to determine the incidence of discomfort and whether it can be related to mismatches between individual anthropometry and related seat and desk dimensions. The study was planned with the following specific objectives:

- To study the different activities, the schoolchildren perform sitting in the classroom.
- To study the dimensions and safety features of the classroom furniture used by these children.
- To assess anthropometric profile of schoolchildren (10-13 yrs) in public schools.
- To correlate the dimensions of classroom furniture with the schoolchildren’s body dimensions.
- To analyze the problems faced by children while sitting on classroom furniture.
METHODS AND MATERIALS

The present study was conducted in public schools of Delhi. Systematic sampling was used for selection of sample.

Selection of schools.

In order to select the schools, the list of schools registered under National Progressive Schools was taken (http://www.npscindia.com). The scrutiny of the list indicated that there were 110 schools as its members.

To identify areas for the study, five public schools in New Delhi were randomly selected. The schools were selected on the basis of cooperation of the school authorities. The selected schools were from five different areas in New Delhi.

Hence, the five public schools finally selected were, Blue Bells School, East of Kailash., Columbia Public School, Vikas Puri, Delhi Police Public School, Safdarjung Enclave, Salwan Public School, Pusa Road, DAV Public School, Sresth Vihar.

SAMPLE SELECTION

After identification of schools, the researcher personally visited the schools under study and selected thirty students (15 boys and 15 girls) from 6th, 7th, 8th standard, students of age groups (10-13 yrs.) were randomly selected from each school making a total of 450 as sample. The researcher herself visited the respective schools and data was collected within the premises of the school.

One of the objectives of the study was to assess the anthropometric profile of school children and to correlate the dimensions of classroom furniture with the schoolchildren anthropometric dimensions. In order to fulfill this objective, an attempt was made to collect anthropometric measurements of 450 school children.
DEVELOPMENT OF TOOLS FOR THE STUDY

The tools comprised of the following:

**Observation checklist**

Observation checklist was used for collecting information about the activities undertaken by children during classroom sitting and for identification of classroom furniture.

**Questionnaire-cum-Interview schedules**

- **For school children**
  An interview-cum-questionnaire schedule was used for collecting information from school children regarding their personal profile, participation in various activities, opinion about fitness of furniture when sitting on, preference about a particular type of furniture, action taken by the students to inform the teacher about the problems faced by them regarding the furniture. A standardized Nordic questionnaire (Standard Nordic questionnaire for analysis of musculoskeletal symptoms (Kuorinka et al., 1987) was used to identify the musculoskeletal pain experienced by children. A structured questionnaire cum interview schedule, comprising of close-ended questions was formulated.

- **For school teachers**
  Class teachers were also interviewed in order to find out the student’s and teacher’s activity pattern, the posture adopted by the children while seated and any complaints made by the children regarding the discomfort in relation to the classroom furniture.

- **For school purchase committee**
  A questionnaire-cum-interview schedule was developed for school purchase committee to find out criterion for selection and purchase of furniture by schools, their budget allocation for the purchase of school furniture, frequency of purchase and place of purchase etc.
Recording Measurements

- Of classroom furniture

One of the objectives of the study was to determine the dimensions of the classroom furniture. Thus, in order to fulfill this, the furniture dimensions were measured in order to make a comparison of the student’s ergonomic needs with the design features of the furniture on the following:

  - seat height, width
  - desk height, width

This was measured for a number of seats and desks available in 6th, 7th, and 8th standard classrooms of all the five public schools. Seat and desk dimensions were measured with a metal tape.

- Of the Anthropometric measurements of school children

Anthropometric measurements were taken for all 450 students selected from five different public schools of New Delhi.

- Correlating the school furniture dimensions with student’s body dimensions to find out the mismatch if any

The anthropometric and furniture measures were combined to examine mismatch (if any) which is defined as incompatibility between the dimensions of the classroom furniture and the dimensions of the school children’s body based on (Parcells et al., 1999; Chaffin and Anderson, 1991) criterion.

The classroom furniture’s dimensions were also compared with the BIS standards (2010) given for school furniture.

TESTING OF THE TOOL

A pretest was performed to ensure the language clarity and applicability of the interview schedule. The schedule was modified on the basis of the responses obtained after conducting the interview with the respondents.
COLLECTION OF DATA

After pre-testing of interview schedule, the final format (Appendix I – IV) was prepared. The process of collection of data was spread over a long period of time and it took nearly two year for data collection.

DATA PROCESSING, ANALYSIS AND INTERPRETATION OF DATA

The entire data of 450 respondents was coded initially before entry. For open ended responses data was also coded (similar responses classified and coded accordingly). Data was entered in excel and cleaned through filtration. Cleaned data set was then imported to SPSS 19.0 by a statistical expert and data validation was conducted before statistical analysis. Basic statistical functions such as frequencies and percentages were calculated. Wherever necessary cross tables were prepared and tests such as chi-square tests and pearson’s correlation was applied to test the significance of the data. Further, data was analyzed and conclusions and inferences were made in the light of the objectives of the study.

RESULTS AND DISCUSSION

Findings of the study, as obtained after the analysis of data, collected by the interview-cum-questionnaire schedule, recording of anthropometric measurements of school children and classroom furniture dimensions are described and discussed in this chapter.

SOCIO-DEMOGRAPHIC INFORMATION

A total number of 450 school children were selected from five public schools. Their personal profile included age and gender.

Age

Age of selected school children ranged from 10yrs to more than 13 years. For the purpose of analysis, sample was divided into three categories which were, children in the age groups of 10-11 years, 12-13 years and >13 years.
Gender

There was more or less equal representation of school children among the three age groups for both boys and girls of all the five schools. There were 76 boys and 83 girls in the age group of 10-11 yrs, 74 boys and 68 girls in the age group of 12-13 yrs, and 75 boys and 74 girls in the age group of > 13 yrs from all the selected five schools. A total of 225 boys and 225 girls were taken for the purpose of analyzing the data.

ACTIVITY PATTERN OF SCHOOL CHILDREN

Children were found to be spending 6 -7 hours per day in schools and out of this, 6 hrs were pure sitting times, that too for long and continuous periods as reported by the school authorities.

Regarding the activities performed by the school children while seated on the classroom furniture, reading, writing, listening to the teacher, crafts and drawing were some of the activities undertaken by them. Further 82.9% of the school children were involved in reading whereas, 84.4% of them in writing as classroom tasks and 86.9% of them were actively listening to the teacher. Art & craft and certain other activities such as leisure reading, watching presentations on screen, quizzes etc. were also found to be undertaken by the school children.

Participation of children in physical activities outside the classroom

Students were found participating even in physical activities outside the classroom along with undertaking these compulsory activities.

It was found that 36.2% children of 10-11 year, 30.2% of 12-13 years, 33.6% of > 13 years age group participated in the physical activities outside the classroom.

On the whole, participation in physical activities was more for boys except for children in the age group of 10-11 years. The reason being, boys are more fun loving and they love to play outdoors. Less participation in physical activities by girls could be due to the fact that as the girls attain puberty at the age of 12 years, so they seem to be uncomfortable and not interested in taking part in physical activities, thereby, allowing their body to cope up with these bodily changes.
Children's desire for having break in between the classes

It was found that, 30.1% of the school children in the age group of 10-11 years, 35.6% of the school children in the age group of 12-13 years, and 34.3% of the school children in the age group of more than 13 years expressed their desire for having break in between the scheduled classes.

ANTHROPOMETRIC PROFILE OF SCHOOL CHILDREN

Results reflected that all anthropometric dimensions of the school children increased as their age increases.

Anthropometric details of school children in the age group of 10-11 years

The mean for stature for boys was found to be (149.9 cm) and for girls it was (144.2 cm).

The mean weight for school boys was (43.8 kg) and for girls it was (41.6 kg).

For stature the 5th percentile value for school boys was (138.0cm) which was more than 5th percentile value for school girls in the same age group (132.0cm).

For the 95th percentile value of stature for school boys was (167.0cm) which was higher than that of the 95th percentile value for schoolgirl (156.0cm.)

Another major observation was that of the weight limit, the 5th percentile value of boys (33 kg) was slightly higher than the 5th percentile vale of girls (30kg).

However, the 95th percentile values for boys (61.0 kg) were slightly more than the 95th percentile girls (55.0 kg).

Anthropometric details of school children in the age group of 12-13 years

The mean for stature for school boys was found to be (150.9 cm) and for girls it was (148.0 cm).

The mean weight for school boys was (45.1 kg) and for girls it was (44.4 kg).

For stature, the 5th percentile value for school boys was (138.0cm) which was slightly more than 5th percentile value for school girls (139.0 cm).
For the 95th percentile value for school boys for stature was (165.0 cm) which was higher than that of the 95th percentile schoolgirls (157.0 cm).

Another major observation was that of the weight limit, the 5th percentile value of both girls and boys was (32 kg). And also the 95th percentile values for boys was (68.0 kg) and for girls it was (64.0 kg).

**Anthropometric details of school children in the age group > 13 years**

The mean for stature school boys was found to be (156.9 cm) and for girls it was (151.4 cm).

The mean weight for school boys was (50.1 kg) and for girls it was (47.3 kg).

For stature, the 5th percentile value for school boys was (147.0 cm) which was more than 5th percentile value for school girls (139.0 cm).

For the 95th percentile value for school boys for stature was (169.0 cm) which was higher than that of the 95th percentile value for schoolgirls (164.0 cm).

Another finding was that of the weight limit, the 5th percentile value of boys was (39.0 kg) that was higher than the 5th percentile value for girls (30.0 kg).

However, the 95th percentile values for boys (70.0 kg) was slightly more than the 95th percentile value for girls (60.0 kg).

Detailed analysis of the anthropometric data are pointer to the fact that boy’s measurements were bigger than girls measurements at all stages of age. School boy’s measurements were found to be more in comparison to the school girls for all the three age groups except for shoulder and elbow height.

The measurements for stature, weight, buttock popliteal, knee height, shoulder elbow arm length, buttock popliteal height were found to be increasing with age. Elbow height, shoulder height and popliteal height showed a slight decrease with age.

Further, it was found that there was a consistent gradual increase in all anthropometric dimensions with age in children of both the sexes. Also, it was found that these students’ anthropometric dimensions varied not only between the different classes, but also within the same class.
CORRELATION BETWEEN ANTHROPOMETRIC MEASUREMENTS AND AGE

The results indicated that the current anthropometric variables were normally distributed.

Moreover, it is also possible to notice the existence of a strong Pearson correlation coefficient between stature and a group of other anthropometric variables. These results indicated that almost all anthropometric dimensions were correlated significantly to each other (P<0.01). The correlation coefficients ranged from 0.02 to 0.529. The highest correlation was found between stature and shoulder height, buttock popliteal, popliteal height and knee height.

DIMENSIONS OF THE CLASSROOM FURNITURE

An attempt was made to undertake measurements of the classroom furniture used by students in all the selected five schools. The furniture dimensions were assessed for their suitability to match the anthropometry of the students. The furniture measurements of the selected five schools were compared with the BIS standards for 10-13 yrs and >13 years school children.

Comparison of selected furniture dimensions with Bureau of Indian Standards (BIS) for children of 10-13 years age group

- In all the schools except for DAV public school, the seat height measurements were high when compared with the BIS standards. Seat width and table width were found to be less for all the selected five schools in comparison to BIS standards.

- Desk height was very high for all the schools.

- Backrest width was found to be high for Delhi Police Public School and Blue Bells School. It was found less in DAV and Salwan Public School. For Columbia public school, the backrest width measurements were found to be in acceptable range as given by the BIS standards.

- Storage width was quite less in all the selected five schools in comparison to the BIS standards.
Comparison of selected furniture dimensions with Bureau of Indian Standards (BIS) for children of >13 years age group

- The seat height measurements were high when compared with the BIS standards.

- Seat width was found to less for DAV, Salwan and Columbia Public School. In Delhi Police Public School, the seat width was found to be greater than the range given by BIS standards. In Blue Bells School, the seat width measurements were found to be in accordance with the BIS standards.

- Table height was very high for all the schools. Table width was also found to be quite less for DAV, Salwan and Columbia Public Schools. Whereas in Delhi Police Public and Blue Bells Schools it was found to be higher than the BIS Standards.

- Backrest width was found to be more for Columbia Public and Blue Bells School, whereas, it was found less for DAV, Salwan and Delhi Police Public School. For Columbia Public School, the backrest width measurements were found to be in acceptable range as given by the BIS standards.

- Storage width was quite less in all the selected five schools in comparison to the BIS standards.

Safety features of the classroom furniture

Researcher, through the analysis found that that majority of students were getting injured because of certain defects in the classroom furniture.

The reasons given by school children in this regard were:

- Faulty construction of the furniture.
- Protruding nails on the furniture.
- Presence of sharp edges/corners
- Broken parts of furniture
• Minimum circulation in the classroom due to congestion of the furniture/minimal distance between the furniture.

Due to these defects in the furniture the school children reported that they also suffered from many injuries.

It was observed that the condition of the classroom furniture was in bad state in most of the schools. The classroom furniture was just another infrastructure which was made available to the students and was not regarded as a basic need for their comfortable sitting.

Further, it was found that the classroom furniture was purchased without due consideration given to the school children’s anthropometric measurements. This may be due to the fact that the school authorities were not aware of the BIS standards recommended for designing classroom furniture.

**CHILDREN’S OPINION ABOUT COMFORT OF FURNITURE**

The student’s opinion about comfort of furniture included the following aspects:

• General comfort of classroom seat and desk

• Back and width of seat

• Height of seat and desk

• Width of desk

• Provision of footrest

*Children’s comfort with regard to classroom furniture*

Results showed that 46.2% of school children opined that they did not have enough space to sit and perform activities comfortably while seated on the classroom furniture.

• The height of the desk was not found proper by 34.2% of children, due to which they were getting fatigued easily.
• Further, 23.6% of children reported that the desks were too narrow and they did not get enough space to place their upper limbs.

• Moreover, 29.8% of school children reported that they found the desk width too narrow and had no space to place their notebooks.

• Also 49.6% school children reported that the backrest was not comfortable which made it difficult for them to maintain a proper posture.

• Around 23% school children reported that they felt cramped and could not change their body position while sitting on the seat.

• Almost 57.3% children reported forward bending while performing various activities sitting on the seat.

• On the whole, 50.7% children reported that they had no place to keep their bags and bottles. A place for keeping bags and water bottles was another aspect which the school children wanted attention on. Children were placing their bags behind their backs while sitting on the seat.

**FORWARD BENDING POSTURE ADOPTED BY CHILDREN**

It was found that 67.7% of school children were bending forwards while working on the desk.

Age-wise comparison of the data showed that 34.8% in (10-11 years), 32.8% in (12-13 years) and 32.5% of school children in the age group (> 13 years) reported forward bending on the desk while performing the sitting tasks.

**RATING OF THE FURNITURE PRESENT IN THE EXISTING GRADE**

The students were further asked to rate their furniture as good, medium or bad. It was found that only 13.1% of school children rated their classroom furniture as good whereas, 51.5% school children rated their furniture to be of medium quality as against 35.3% of school children who reported the classroom furniture to be of bad quality.
COMPLAINTS MADE BY CHILDREN REGARDING FURNITURE PROBLEMS

An attempt was made by the researcher to enquire from school children if they were raising any complaints to the school authorities for the problems faced by them while sitting on the furniture.

It was also seen that greater percentage of boys in comparison to girls from all the schools complained regarding the furniture problems that they faced. This may be due to the fact that boys generally show more aggression and are more assertive than the girls.

Action taken by the teachers for children’s complaints on classroom furniture

Actions taken by the school teachers regarding the children’s complaints were as follows:

- Children were asked to manage on their own
- Assurance by teacher that the furniture would be changed
- The furniture was replaced
- No response was given by teachers

SELF – REPORTED PAINS EXPERIENCED BY SCHOOL CHILDREN

Analysis of the findings showed that children from all the three age groups complained of musculoskeletal pains of various types:

- Around 45% boys and 55.3% girls (10-11 years) reported pain in cervical spine. More percentage of boys in comparison to girls expressed cervical spine pain from 12-13 years and >13 years age group.

- For 10-11 years, 50% of boys and girls reported pain in cervical and thoracic spine. Also 56% of boys and 44% girls (12-13 years) and 34.3% of boys and 65.7% of girls (>13 years) reported to have pain in the cervical and thoracic spine.
• Of the total sample, 24.2% children reported pain in leg as the major complaint, followed by discomfort in wrist joint (20.9%), elbow joint (19.6%), hip (18.7%), shoulder joint (18.7%), lower arm (18%), feet numbness (15.8%), knee joint (12.7%), and upper arm (11.1%).

• On further analyzing the data, more of girls in comparison to boys were found to have experienced pain for different body parts. This could be due to gender differences as the physical and physiological characteristics of males and females are different. Males and females differ in their muscle strength as females tend to have lower muscle strength than males, particularly in the upper limb musculature.

• A total of 14.1% of school children reported ‘always’ having back pain whereas, 46.4% school children reported having back pain only ‘sometimes’ during the day. On the other hand, 39.5% never had any back pain while seated.

• Neck pain was one of the many musculoskeletal disorder experienced by school children, followed by other pains as reported by earlier findings. Higher percentage of boys reported always having neck pain than girls for all the three age groups. The greater percentage of boys reporting neck pain could be because of their higher stature measurements in comparison to girls and hence had to adopt a forward leaning posture.

SCHOOL CHILDREN’S PREFERENCE FOR CLASSROOM FURNITURE

The preferences of school children regarding school furniture were taken in order to understand their expectations from the classroom furniture and also to know their varied choices. A total of 53.1% school children showed preferences for their classroom furniture on which they would like to sit upon.

The preferences given by school children for classroom furniture were for a better quality of desks and seat with the following features:

• Availability of book compartments.

• Comfortable individual desk top and seat without any sharp corners
• Desks and seats with proper height for each student

• Furniture with proper joinery (no nails coming out)

• Good material to be used for designing classroom seats and desks

**OPINION OF TEACHERS REGARDING CLASSROOM FURNITURE**

Teachers expressed their dissatisfaction with the classroom furniture provided to the children with regard to the material used for the construction of furniture, its dimensions, the height of joinery used, height of desk and the seat depth. They also reported that children’s sometimes complained of body pains during school hours. This included pain in the back, leg, neck and shoulder etc.

Teachers also felt that the school furniture should be designed to support good posture.

It was of interest to note that teachers expressed their desire to incorporate a strong, general, ergonomic course into the school curriculum

**RESPONSE OF SCHOOL PURCHASE COMMITTEE**

The school purchase committee response was taken regarding the pattern of purchase of the classroom furniture. All the school purchase committee reported that they were purchasing the classroom furniture without giving any due consideration to the BIS standards as they were not aware of it. The furniture was purchased in bulk and none of the schools had any knowledge about the anthropometric measurements of school children. Hence they were not getting the classroom furniture made as per anthropometric measurements. The furniture was made by the dealers on the standard conventional measurements.

**CORRELATION BETWEEN FURNITURE AND STUDENT’S ANTHROPOMETRIC DIMENSIONS**

In order to find out the mismatch between classroom furniture and children’s anthropometric measurement, the anthropometric measurements were correlated with the furniture measurements.
The mismatch between children’s anthropometric measurements and furniture dimensions is calculated based on the rules adapted from Parcells et al., (1999).

**Popliteal height and seat height mismatch**

A mismatch is defined when the seat depth was either 95% or 88% of the popliteal height.

- All the schools except Salwan public school had mismatch between seat height and popliteal height.
- The existing seats were too high in all these schools. However, seat heights in Blue Bells and Columbia public school were exceptionally higher.

**Buttock-popliteal length and seat depth mismatch**

A mismatch is defined when the seat depth was either 95% or 80% of the popliteal height.

With reference to the criteria of seat depth mismatch and buttock popliteal length, it was observed that there was a mismatch in DAV, Blue Bells, Salwan, Columbia Public School for both the age group except in Delhi Police Public School for >13 years age group.

**Knee rest height and desk height mismatch**

To be comfortable, desk–knee clearance should exceed 2 cm. A mismatch is defined as occurring when a desk was 2 cm higher than the knee height. It was seen that none of the schools had a mismatch between knee rest height and desk height mismatch.

**Elbow rest height and desk height mismatch**

Elbow rest height depends not only on vertical elbow, but also the shoulder flexion and shoulder abduction angles. To determine acceptable elbow rest height with shoulder flexion and abduction (hE), the measurements of shoulder height (hS), vertical elbow height (hEv) upper arm length (= hS- hEv), shoulder flexion ( ), and shoulder abduction (β) will be used in the following equation:

\[ hE = hEv + \mu [(1-\cos(\theta)) + \cos(\beta)] \]
With this formula and the maximum acceptable angles suggested by Chaffin and Anderson (1991), it is possible to determine the maximum and minimum desk height appropriate for each student. With minimum and maximum shoulder flexions of 0° and 25°, the corresponding cosines are 1 (0°) and .9063 (25°). For abduction angles of 0° (minimum) and 20° (maximum), the corresponding cosines are 1 and 0.9397. Given that the cosines are monotone functions of the angles, a student’s minimum desk height is determined by the vertical elbow height alone:

\[ h_E = h_{Ev} + \mu \left[ (1-0.9063) + 0.9063 \right] \]

The maximum desk height is determined by:

\[ h_E = h_{Ev} + \mu \left[ (1-0.9063) + 0.9063 \right] = h_{Ev} + \mu (0.1483) \]

\[ = h_{Ev} + 0.1483 hS - 0.1483 h_{Ev} = 0.8517 h_{Ev} + 0.1483 hS, \text{ since } \mu = hS - h_{Ev}. \]

Thus, the maximum desk height acceptable for a student was determined by students' shoulder height and vertical elbow height and can be calculated on the basis of the collected information.

Based on the above dimensions, a mismatch of elbow rest height and desk height is defined as when the desk was either shorter than the minimum desk height or taller than the maximum desk height as suggested by Parcells et al., (1999).

In all the schools, there was a mismatch between elbow rest height and desk height as the results showed that the observed desk height was more than the maximum desk height.

Anthropometric mismatches can have serious consequences for comfort and efficiency because of the way they increase the postural load on the body. The results of the analysis indicate that appropriate ergonomics–oriented classroom furniture could be designed based on the data obtained from the intended users. In most cases, improper desk-seat combinations are often the major reasons that children experience some level of discomfort while in the classroom. According to the obtained data, it can be concluded that classroom furniture was not adequate for the student population. The results of this study highlight the fact that classroom furniture is typically acquired and selected without any previous ergonomics concern, which will, most likely, result in its adequacy.
OUTCOME OF THE STUDY

- The data in this study indicate a substantial degree of mismatch between the bodily dimensions of these sixth through eighth graders and the classroom furniture available to them.

- Students are sitting in seats that are too high or too low and at desks that are too high. The only positive finding is that knee height/desk clearance was not a problem for any student. The data also showed substantial variability in students’ bodily dimensions, an expected finding for this age group. Thus, it is unlikely that any furniture with fixed dimensions is going to accommodate a majority of students.

- Stature or body height is shown to be a good predictor of whether a student fits into a chair.

- If manufacturers are going to continue to produce and sell traditionally designed furniture, schools need to be encouraged to at least provide as much variety in furniture sizes as possible to accommodate the variety of student sizes. In this particular study, school furniture simply turned out to be too large for many sixth, seventh, and eighth graders.

However, it is also important that health professionals working in schools be aware that full accommodation of students’ needs would require ergonomically redesigned classroom furniture.