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The ergonomic design of classroom furniture/computer work station for first graders in the elementary school

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A R T I C L E I N F O

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A B S T R A C T

Children have been known to spend over 30% of their time at school. Most classroom activities involve sitting for long periods of time, with little or no breaks. Every effort should be made to ensure that young children do not experience back pain and other musculoskeletal disorders due to prolonged sitting on improperly designed classroom furniture. This paper proposes a methodology and guidelines for the design of ergonomic-oriented classroom furniture for first graders in the elementary school. The anthropometric measures of twenty first graders were used to develop regression equations for the furniture dimensions. The analysis of the relevant anthropometric measures such as stature, weight, body mass index (BMI), popliteal height, buttock-popliteal length, and hip breadth shows that stature and body mass index are important factors in the design of the classroom furniture. Adjustability was incorporated into the design in order to recommend the appropriate dimensions for the design of the classroom furniture. Based on the need to accommodate at least 90% of the population of first graders in the United States, this paper proposes furniture design dimensions for seat height (25.83–32.23 cm); seat depth (27.41–33.86 cm); seat width (17.91–23.29 cm); back rest (35.64–44.37 cm); arm rest (16.28–20.68 cm); and desk height (30.12–37.85 cm). This anthropometric analysis could be used to design ergonomic-oriented classroom furniture which would not only incorporate adjustability, but also improve the level of comfort for the intended users.

1. Introduction

The use of furniture has been traced back to the Stone Age, during this period, the handy man carved out chairs and tables from stones and rocks. In the ancient civilization, the chair was one of the first types of furniture which was created in order to convey status, kingship and authority. Recent archeologists have discovered images of early furniture of ancient civilizations, especially in Ancient Egypt. The chair and table changed very little for several thousand years. The chair was typically pictured with a low seat and slightly reclining back as seen in the thrones and folding stools of the Egyptian Pharaohs (Schwartz et al., 1968).

Furniture designs continued to change over time, and by the mid 19th century, the influence of Industrial Revolution and mass production further enabled chairs and tables to be manufactured in large quantities, various sizes and forms (Fiell and Fiell, 1993). 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 (Lueder and Rice, 2007). Although adjustability has been a primary criterion in many designs, by the early 1960s, the value of adjustable furniture became an issue for debate in cases where there are more than two dimensions to adjust and users have difficulty in determining what fits best, which is often worsened by fatigue. By the early 1990s several manufacturers commenced the mass production of the modern furniture, especially chairs in different sizes and dimensions, based on reliance on the anthropometric data available to the designers (Cranz, 1998). Actual chair and desk dimensions are determined by measurements of the human body or anthropometric measurements. Anthropometric statistics may be gathered for mass produced furniture and designs are made based on these statistics.

Until recently, the design of school furniture for children 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. Numerous researches investigated prolonged sitting

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in the work place and proposed design principles for chairs and desks, especially for the computer workstation (Cook and Kothiyal, 1998; Kumar, 1994; Villanueva et al., 1996; Burgess-Limerick et al., 1999). Although several ergonomic-oriented designs have been proposed for classroom furniture, this research intends to effectively recommend design guidelines for elementary school furniture by conducting an initial evaluation of the current furniture design in a particular school. Further analysis is then carried out to obtain the relevant design parameters and dimensions for the ergonomic-oriented classroom furniture based on the need to adequately accommodate at least 90% of the entire population of first graders in the United States.

1.1. Research motivation

Several elementary schools in United States and around the world, especially in developing countries are often faced with ergonomics-oriented problem of inability to match students with the available classroom furniture, desks or computer work stations (Panagiotopoulou et al., 2004; Gouvali and Boudolosa, 2006). Economical problems, budget constraints and lack of educational funding in several countries have also led to the problem of inadequate class room furniture in the elementary schools. Overcrowding and increase in student population is also one of the major problems facing numerous elementary schools (Rumberger, 2002; Ready et al., 2004). It should also be noted that anthropometric dimensions of children such as stature, weight, and body mass index (BMI) have increased over the years. This is due to changes in their standard of living, eating habits and lack of adequate exercise (Figueroa-Colon et al., 1997; Jung, 2005; Jackson-Leach and Lobstein, 2006). In the quest of designing effective ergonomic-centered classroom furniture for elementary school children, it will be very important to examine the design of the existing furniture in the school by performing general inspections. In this research, a local elementary school was selected and the existing furniture was examined based on the functional efficiency, ease of use, comfort, as well as health and safety (Pheasant, 1998). Examination of the current furniture in the elementary school revealed several design inadequacies such as the lack of cushion on the hardwood benches, and ergonomic concerns such as elongated benches and desks which do not have back rests. Other observed problems include overpopulation, where at least 6 children seated on a bench which was initially designed to seat only 3 or 4 children. In addition to this, several children complained of body aches and pains, which could be an indication of the ergonomic problems and design flaws identified during the inspection of the classroom furniture.

In order to provide a tangible justification for this study, 126 first graders, 66 boys and 60 girls (average age of 6.5 years) were randomly selected from three additional elementary schools and each student was given a questionnaire to complete. In order to protect the confidentiality of the investigation, the names of the children were not required on the questionnaire. The result obtained from the survey is similar to the survey conducted by Parcells et al. (1999). The survey revealed that the majority of the children (95%) attended classes more than three times a week and were seated in the classroom for more than four hours daily (93%). This shows that children spend a huge part of their school hours in the classroom. Storr-Paulsen and Aagaard-Hansen (1994) observed that 8 and 9 year old children often tend to sit for more than an hour within any given hour and half. According to Dillon (1976), nursery school children are seated for almost 40% of their time in the classroom. Sitting still for a long period of time can cause the blood to move more slowly. Blood pools in the larger veins of the legs, and clots may form leading to a medical condition known as deep venous thrombosis (DVT). A large number of the students also claimed that their classroom furniture was not comfortable.

Additionally, approximately 58% of the children claimed to have been absent from school at least once in the last 4 weeks, primarily due to aches and pains. The rating of the severity of the aches and pains and how often the aches and pains occurred revealed that over 50% of the children experienced pains and aches in each of the following major areas of their body: neck area, low back, hips, buttocks, thighs, wrists, knees, hands, and the ankles. The degree of pain ranges from slight to unbearable, and often occur either everyday or sporadically. The result of this survey provided sufficient justification for further research based on the need to provide effective recommendations for the design of ergonomic-oriented classroom furniture for the first graders since school children have been found to often spend over 30% of their time at school (Linton et al., 1994).

2. Literature review

Several researchers have proposed numerous methodologies for various furniture designs in the past. Until recently, the design of school furniture for children 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. In order to effectively design the classroom furniture for first graders, it is important to acquire the necessary background information which would be useful in proposing the experimental design methodology. Numerous researches investigated prolonged sitting in the work place and proposed design principles for chairs and desks, especially for the computer workstation (Cook and Kothiyal, 1998; Kumar, 1994; Burgess-Limerick et al., 1999).

Several research studies have shown that children often remain seated in the classroom for a considerable amount of time (Linton et al., 1994; Kumar, 1994). Prolonged sitting position and static posture in a forward bending manner have been found to be the major cause of low back pain (Salminen, 1984; Balague et al., 1988; Troussier et al., 1994). The problem of back pain is not limited to adults only, as studies have indicated that a huge number of school children have been reported to have back pains and neck pains (Niemi et al., 1997; Olsen et al., 1992). All over the world, increasing population of school children are now noted to be at severe risk of musculoskeletal injuries, postural stresses and strains which could occur due to increasing body size, prolonged sitting position and awkward postures (Evans et al., 1992; Mokdad and Al-Ansari, 2009). Awkward sitting position and posture puts extreme strain on the muscles, the ligaments and on lumbosacral joints (L5/S1) as well as other vertebral discs (Bendix, 1987; Brunswic, 1984). Mandal (1985) and Evans et al. (1992) argued that the occurrence of low back pain among school children could be linked to improper designs of school furniture.

The classroom furniture plays a very important role in the maintenance of good sitting position. Yeats (1997) indicated that the classroom furniture design serves a vital part in the long-term sitting posture of children. Unlike adults, proper sitting posture is found to be more important to children since sitting habits acquired at this stage may be extremely difficult to change later in life. Knight and Noyes (1999) identified the major functions of the school furniture in their research. Classroom furniture is known to provide support to the children when during class activities or when writing on the table. In addition to ensuring that distractions are minimized, comfortable classroom furniture have been noted to enhance effective learning, since the performances and behaviors of children can be easily monitored when seated. When designing classroom furniture, easy mobility of the children should be considered since localized muscle fatigue could set in due to prolonged immobility (Laville, 1985).

Tichauer (1978) investigated the dynamics of sitting by studying the mechanics of the human body with respect to the furniture. The investigation showed that 75% of the entire body weight is supported by the ischial tuberocities, which are the weight bearing parts of the pelvis. Excessive compressive stresses occur at this point; the center of gravity of the seated individual might not be directly aligned with the tuberocities. As a result of this, the tuberocities might not be able to provide the full support needed for the body weight. Branton (1969) argued that the use of the legs and the back are needed to provide the balance needed when an individual is seated. Leg support helps to distribute and reduce the loads in the thighs and buttocks (Nag et al., 2008). 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. Proper sitting posture is necessary to prevent the backward rotation of the pelvis and lumbar kyphosis. Support to the sacrum and pelvic areas are needed by the lumbar lordosis in order to maintain the weight on the ischial tuberocities. The lumbar lordosis is the normal anterior curve of the lumbar vertebrae which distributes as much as a quarter of the weight to posterior thighs (Drummond et al., 1982). Sitting-up straight is recommended in order to maintain a lumbar curvature which is assumed as the ideal sitting posture. Unfortunately, this sitting position cannot be fully maintained for a long period of time (Mandal, 1981). The sit-up straight requirement has been adopted in the design of school furniture in the United Kingdom (Karvonen et al., 1962). Sitting in an erect position without adequate back rest may be difficult to achieve.

Several design standards and guidelines have been proposed for the development in the classroom furniture in the past. An early effort in the development of a general standard and guidelines for the designs of ergonomic-centered classroom furniture includes the ISO 5970 – 1979 (Standards for tables and chairs for educational institutions). ISO 5970 – 1979 was developed by the International Standards Organization (ISO) based on the need to ensure good seating postures while in the classroom. Although quite out-dated, recent researchers have continued to compare their analysis with the ISO 5970 – 1979 anthropometric database (Jung, 2005). In an effort to improve the level of seating comfort, Bendix et al. (1983) developed a forward inclined seat at 5° and a table whose height is a little above the elbow height. A tilted desk with an inclination of 35°–45° was recommended. Although the sloping desk improved the posture of the subjects studied, the design did not accommodate a larger population of school children of different body sizes and statures. Wall et al. (1991) investigated sitting posture by developing a desk which was inclined at 10°. Although the design improved the position and erection of the head and trunk by 6° and 7° respectively when the desk was used, the fixed nature of the design made it difficult to adjust the angle of inclination for ingress and egress. Hence, there is a need for the incorporation of adjustability in the design.

The incorporation of adjustability in the design of school furniture has been emphasized for increased accommodation of variations in anthropometric measures, and individual differences in ethnicity and cultural background (Evans et al., 1988; Parcells et al., 1999). Jeong and Park (1990) emphasized the need to effectively obtain children's anthropometric measures. Anthropometric measures for children vary across different age groups, genders, cultures, races and ethnic backgrounds. As a result of this, it is possible for children's anthropometric dimensions to vary not only within age groups but within the same class, since a class could be comprised of children of different races, ethnic backgrounds, statures and weights. Therefore, it may be impossible for a fixed furniture design to accommodate a large population of children.

Gender differences should also be considered when designing classroom furniture based on anthropometric measurements. Jeong and Park (1990) conducted an observation with school children of different gender. They observed that sexual differences between stature, body mass index (BMI) and other body dimensions played a very significant impact on the results of the experiment. The findings revealed that most boys required higher desk and chair heights than girls while girls required larger chair depths and breadths than boys of similar stature. Therefore, in addition to accommodation of larger population of users, Yeats (1997) suggested that adjustability is also necessary to improve ease of use, increased comfort, and decrease cases of body aches and pains.

In order to determine the accommodation range and adjustability, anthropometric measurements are necessary. Anthropometric measurements are an important factor that should be taken into account in school furniture design. In the design of classroom furniture, specific anthropometric measurements, such as popliteal height, knee height, buttock-popliteal length and elbow height are needed for the determination of the furniture dimensions which are important to achieve the correct sitting posture (Knight and Noyes, 1999; Parcells et al., 1999; Miller, 2000). Yeats (1997) argued that good sitting posture is enhanced by classroom activities, the anthropometric measures of school children as well as the measures and design features of classroom furniture.

Although adjustability is always incorporated in the design of the overall height of chairs, unfortunately, the "one-size-fits-all' methodology is still being used in the design of the seat, arms and back rests of most chairs. This is often due to the need for low cost in manufacturing and sales. In 1993, Lane and Richardson conducted an investigative study to determine whether classroom furniture manufacturing companies in the United States relied on anthropometric data in their manufacturing processes. The results of their survey showed that a majority of the furniture manufacturers did not base their designs on the appropriate anthropometric measurements and the ergonomic considerations of their intended users. Existing designs have remained the same for decades, despite changes in the individual body sizes of the children.

In developing countries, most classroom furniture has been found to have caused more distractions and injuries to the children than the provision of learning support. Hui Zhu et al. (1998) noted that most classroom furniture in developing countries lacked quality and are often manufactured with woods which offer very rough writing surfaces. It is therefore important to design classroom furniture based on the necessary anthropometric measures. For the design of desks/ tables, several researchers have incorporated measurements obtained from the elbow height in their designs (Parcells et al., 1999). If the elbow height exceeds the height of a desk or table, the users may tend to reach for the writing material or the computer keyboard by bending forward. As a result of this, spinal flexion occurs and the body weight is distributed to the arms, thereby leading to kyphotic spinal posture with round shoulders. Chaffin et al. (2006) recommends a shoulder flexion angle of 25° and a shoulder abduction angle of between 15° and 20° when performing deskwork on a workstation.

In developed European countries like England, Germany and France, several efforts have been made to introduce uniform classroom furniture design guidelines and standards. For example, in England, the New British and European Educational Furniture Standard, also known as the New European Standards for Classroom Furniture (EN1729, Parts 1 and 2) was introduced in 2007 for the design of tables, chairs and workstation desks, based on the anthropometric measurements of over 1500 children in the United Kingdom in 2001. This New British and European Educational

Furniture Standard has been considered as the only compelling standard for classroom furniture, since it was the first time in over forty years that an extensive research was conducted in order to update the anthropometric measurement database of school children in the United Kingdom. According to the British Standard Institute (2007), the first part (Part 1) of the standard ensures that the size and dimensions of the furniture is in compliance with the set guidelines. This is necessary to prevent awkward seating postures which could lead to back pain. The second part (Part 2) of the standard ensures that the furniture is durable in terms of strength and stability. Since classroom furniture is often used continuously, it is important to make sure that the product is capable of withstanding rigorous use.

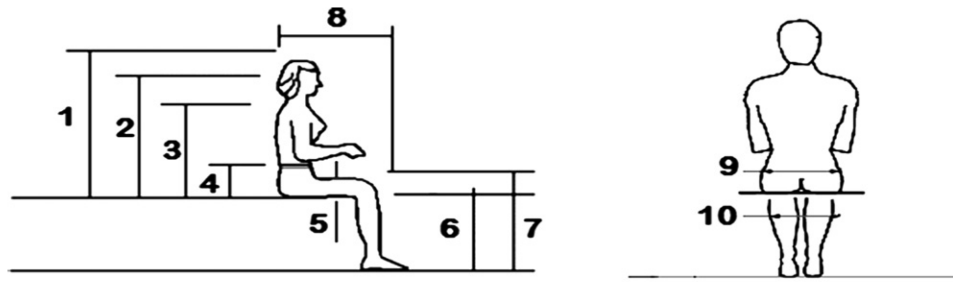
The increasing rate of computer usage in the classroom made it necessary to consider adequate measurements when designing a workstation. Harris and Straker (2000) found out that over 60% of children suffer some form of discomfort or the other when using a desktop computer or a laptop. The findings of the research work indicated that many school computers are set up without the necessary ergonomic considerations such as typing postures, and key board height. This increases the risk of children developing cumulative trauma disorders such as carpal tunnel and tendonitis. In an effort to design a desk or a workstation which would be appropriate for writing and the use of computer at the same time, Laeser et al. (1998) conducted an experiment based on the evaluation of elementary school children. The results of the study revealed that most desk/workstations are often too high when typing on the computer or when looking at the monitor. Several awkward postures were observed for 95 children in 11 elementary schools. In a related research study, Saarnia et al. (2009) examined the sitting postures and its effect on the spine and mobility of school children when working on computer workstation. Unfortunately, their research indicated that additional improvement to the existing workstation did not affect the level of comfort of the children. This paper therefore, intends to draw upon the current literature by the obtaining the relevant anthropometric measurements of first graders, and proposing design parameters and dimensions for ergonomics-oriented classroom furniture in order to reduce back pain and other musculoskeletal disorders.

3. Methodology/experimental design

It may be unrealistic to attempt to develop a classroom furniture design that “fits all” since children continue to grow and often leave for the next grade at the end of the academic session. It is therefore, unwise to design specific or custom made furniture for a particular elementary school student. This research intends to propose guidelines and parameters for the design of ergonomic-oriented classroom furniture which would accommodate at least 90% of all first graders in elementary schools across the United States. Twenty ($n = 20$) children, 12 males and 8 females, between the ages of 6 and 7 years old, typically first graders from three elementary schools in the central Pennsylvania region were randomly selected for the experimental analysis. Prior to the experiment, an informed consent form stating the title of the investigation, the objective of the investigation, procedures to be followed, possible discomforts or risks associated with the experiment, the benefits of conducting the experiment, the possible duration of time of the procedures, right to ask questions, statement of confidentiality, any payment for participation, contact details of the investigator, nature of participation (voluntary or obligated), as well as injury/litigation (liability) clause was given to each of the subjects and were required to be signed by the subjects as well as a parent/guardian. The signed consent forms were collected before the commencement of the experiment. The experiment was estimated to last 2–3 hours in time duration. Standard anthropometric measurements were used in obtaining the body dimensions of each subject and in accordance to measuring techniques proposed by Parcells et al. (1999), all anthropometric measures were taken with the subject in a relaxed and exact posture on a flat surface. Excessive clothing such as jackets, overalls, socks, and shoes were removed and the subjects were measured in T-shirts and shorts.

The weight scale was set to zero at the beginning of the experiment in order to reduce measurement errors. In order to maintain the accuracy in the stature measurement, braids, or hairstyles that might interfere with the readings were brushed aside or flattened as much as possible. To obtain the weights, the subjects were told to step onto the weighing scale and look straight ahead. For the stature or height measurement, the subjects were measured against a board or vertical flat surface (wall) from the top of the head to the feet. Then a point marker was used to note the highest point at the top of the head. In addition to stature and weight, other relevant anthropometric dimensions which are necessary for the seat and work surface design was obtained using the United States Army Anthropometric Survey (ANUSR) definition and anthropometric measuring techniques. In 1988 the United States Army developed over 240 anthropometric measures in order to conduct a military anthropometric survey of uniformed men and women. The ANSUR statistical data is based on over 40 anthropometric surveys of United States military personnel between 1945 and 1988 which comprises of over 75,000 past and present military personnel (Clauser et al., 1988). An adjustable chair was used to obtain the seated anthropometric dimensions for each subject when sitting at a knee flexion angle of 90°. In addition to stature and weight, the following anthropometric dimensions which are necessary for the seat and work surface design were obtained.

1. *Sitting Height:* This is the vertical distance from the tip of the head to the surface of the sitting object (stool). Using an anthropometer, the subjects were measured when sitting erect with their heads in the Frankfort plane, with their thighs parallel and the feet in line with the thighs, at a knee flexion angle of 90°. The subjects' shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other (Clauser, et al., 1988). The sitting height is shown in Fig. 1.
2. *Eye Height:* This is the vertical distance from the sitting surface to the ectocanthus landmark on the outer corner of the right eye (ANSUR, 1988). The eye height is shown in Fig 1.
3. *Shoulder Height:* This is the vertical distance from the top of the shoulder at the acromion process to the subject's sitting surface (ANSUR, 1988). The shoulder height is shown in Fig. 1.
4. *Elbow Height:* This is the vertical distance from the bottom of the tip of the elbow (olecranon) to the subject's seated surface (ANSUR, 1988). The elbow height was measured at an elbow flexion angle of 90°. The elbow height is shown in Fig. 1.
5. *Thigh Clearance:* This is the vertical distance between a surface of the stool and the highest point on the top of the right thigh. Using an anthropometer, the thigh clearance of the subjects was measured when sitting with their thighs parallel and the feet in line with the thighs, at a knee flexion angle of 90°. The thigh clearance is shown in Fig. 1.
6. *Popliteal Height:* This is the vertical distance from the popliteal space which is the posterior surface of the knee to the foot resting surface (Clauser, et al., 1988). The popliteal heights of the subjects were measured at a knee flexion angle of 90°. The popliteal height is shown in Fig. 1.
7. *Knee Height:* This is the vertical distance from the foot resting surface to the top of the knee cap (Clauser, et al., 1988). This is measured just above the patella at a knee flexion angle of 90°. The knee height is shown in Fig. 1.



1	Sitting Height
2	Eye Height
3	Shoulder Height
4	Elbow Rest Height
5	Thigh Clearance
6	Popliteal Height (Stool Height)
7	Knee Height
8	Buttock-Popliteal Length
9	Hip Breadth
10	Knee-to-Knee Breadth

Fig. 1. Anthropometric measures for furniture design.

8. *Buttock-Popliteal Length/Thigh Length:* This is the distance from the posterior surface of the buttock to the posterior surface of the knee or popliteal surface (Clauser, et al., 1988). The buttock-popliteal length was measured at a knee flexion angle of 90°. The buttock-popliteal length is shown in Fig. 1.
9. *Hip Breadth:* The hip breath is the distance between the right side of the pelvic and the left side, measured when seated (Clauser, et al., 1988). The hip breadth is shown in Fig. 1.
10. *Knee-to-Knee Breadth:* This is the distance from the left end of the left knee to the right side end of the right knee (Clauser, et al., 1988). The knee-to-knee breadth is shown in Fig. 1.
11. *Upper Arm Length:* This is the difference obtained between the elbow height and shoulder height (Clauser, et al., 1988).

4. Results and discussion

The analysis of the obtained anthropometric data and computation of descriptive statistics (Mean, Range, Standard Deviation and Standard Error of the Mean) was conducted using Microsoft Excel for Windows Operating System/Platform. Table 1 shows the descriptive statistics of the obtained measurements of the body dimensions of the subjects.

4.1. Furniture design guidelines

4.1.1. Seat design

For the seat design, three factors of accommodation limits are considered. These are the seat depth, width and height. In order to obtain the seat depth, width and height, the following equations or regression relationships (Equations (1)–(3)) are proposed. It is assumed that stature is a good predictor of the popliteal height (PH), and the buttock-popliteal length (BPL) while the BMI is a good predictor of the hip breadth. The BMI was obtained by multiplying the weight of each subject by the square of their respective statures. In establishing a relationship between the body dimensions, the stature was chosen as the primary predictor of the other body segments. This is in accordance with the analysis conducted by Roebuck et al. (1975) which showed that some of the body segment lengths could be expressed as a proportion of stature. The seat height is assumed to be proportional to the popliteal height. Although measured, popliteal height could also be determined as a function of the stature (Equation (1)).

$$\text{Popliteal height (PH)} = a + b^{*}\text{Stature} + N(0, s) \tag{1}$$

Table 1
Anthropometric measures of the body dimensions of the subjects.

Body Dimension	Minimum	Maximum	Mean	Range	Standard Deviation	Standard Error
Stature (cm)	106.68	138.07	120.19	31.39	8.84	1.98
Weight (kg)	19.51	34.03	25.67	14.52	3.76	0.84
Body Mass Index (BMI)	11.90	21.97	17.98	10.07	2.11	0.47
Elbow Height (cm)	16.43	20.88	18.56	4.45	1.29	0.29
Sitting Shoulder Height (cm)	36.50	45.11	40.17	8.61	2.55	0.57
Upper Arm Length (cm)	19.84	25.04	22.36	5.21	1.33	0.30
Hip Breadth (cm)	19.69	27.97	23.42	8.28	2.45	0.55
Sitting Knee Height (cm)	30.40	38.38	34.13	7.98	2.25	0.50
Sitting Popliteal Height (cm)	26.14	32.99	29.31	6.86	1.86	0.42
Buttock-Popliteal Length (cm)	27.20	34.34	30.75	7.14	1.93	0.43

a and b are constants and $N(0, s)$ indicates that the data is obtained from a normal distribution.

From the relationship in Equation (1), the seat height can be determined (Equation (2)).

$$\text{Seat Height (SH)} = a + b^{*}\text{PH} + N(0, s) \tag{2}$$

The seat depth is assumed to be proportional to the buttock-popliteal length (BPL). The BPL is assumed to be a function of the stature. Therefore, a relationship between the stature and the BPL could be established (Equation (3)).

$$\text{Buttock-Popliteal Length (BPL)} = a + b^{*}\text{stature} + N(0, s) \tag{3}$$

In order to determine the seat width, the seat width is assumed to be proportional to the hip breath (HB). The hip breath is assumed to be a function of the BMI; therefore, a relationship could be established to obtain the seat width as shown in Equation (4).

$$\text{Width or Hip Breath (HB)} = a + b^{*}\text{BMI} + N(0, s) \tag{4}$$

In order to determine accommodations for larger population of users, the following criteria are suggested.

1. The hip breadth (HP) should be shorter than the furniture width (the shaded area in Fig. 2 shows the anticipated population accommodation).
2. The buttock-popliteal length (BPL) should be bigger than the depth of the seat (the shaded area in Fig. 3 shows the anticipated population accommodation).
3. The seat height (SH) should be greater than the popliteal height should (the shaded area in Fig. 4 shows the population accommodation).

In addition to the assumptions made above, the arm rest and the back rest design are also based on the relationship between the stature and the shoulder height (for back rest) as well as the relationship between the stature and the elbow height (for the arm rest).

4.1.2. Work station/desk design

For the design of the workstation desk, it was assumed that the knee height is proportional to the table height, knee height is assumed to be a function of the stature. When incorporating adjustability to the desk design, the preferred angle of inclination should be between 15° to 20° as recommended by Chaffin et al. (2006). This will also account for the eye level inclination (viewing angle) when gazing at the computer monitor. Further analysis, using regression equations (R^2-values ranging from 0.70 to 0.93; $p < 0.0001$) of the anthropometric measures provided the following equations:

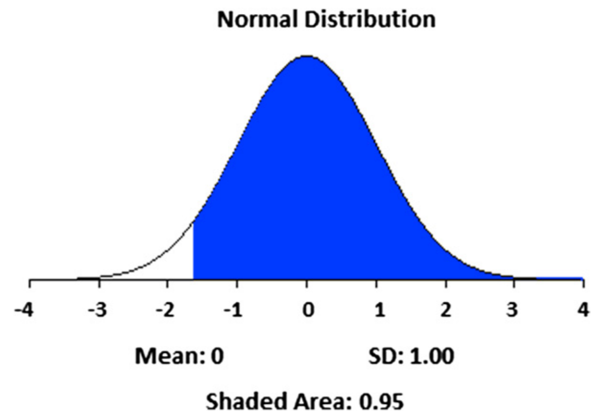


Fig. 3. Buttock-popliteal length accommodation.

$$\text{Popliteal Height (PH)} = 0.2705 + 0.24^{*}(\text{Stature}) \tag{5}$$

$$\text{Buttock-Popliteal Length (BPL)} = 0.7188 + 0.2426^{*}(\text{Stature}) \tag{6}$$

$$\text{Hip Breadth (HP)} = 0.6444 + 0.4729^{*}(\text{BMI}) \tag{7}$$

$$\text{Shoulder Height (SH)} = 0.4416 + 0.3274^{*}(\text{Stature}) \tag{8}$$

$$\text{Elbow Height (EH)} = -0.4142 + 0.21645^{*}(\text{Stature}) \tag{9}$$

$$\text{Knee Height (KH)} = 0.4416 + 0.3274^{*}(\text{Stature}) \tag{10}$$

When designing classroom furniture for children, it is important to ensure that the undesirable effects of sitting for long periods of time is reduced by endeavoring to make the furniture fit the user (Shackel et al., 1976). In some cases, fitting a population rather than an individual could be much more complex (Melzer and Moffitt, 1997). A design may not fit most of a target population, especially if the design is based on the average dimensions of the population. For example, the seat width and height of a particular group of children may vary based on the individual differences highlighted earlier on. It is therefore important to consider a better way of setting the accommodation criteria in order to design for a larger population size. The design guidelines for the proposed ergonomics-centered classroom furniture was obtained using the growth charts for boys and girls (2–20 years) developed by the National Center for Health Statistics (NCHS) and the National Center for Chronic Disease Prevention and Health Promotion. The

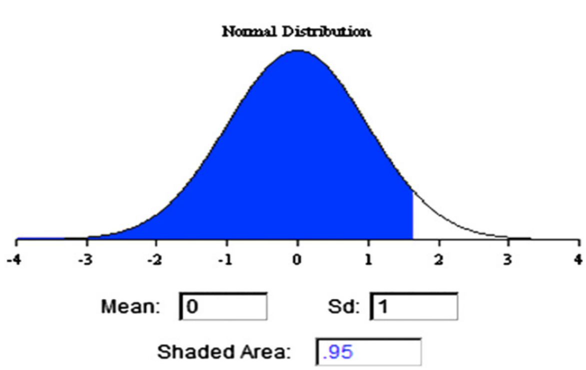


Fig. 2. Hip breadth accommodation.

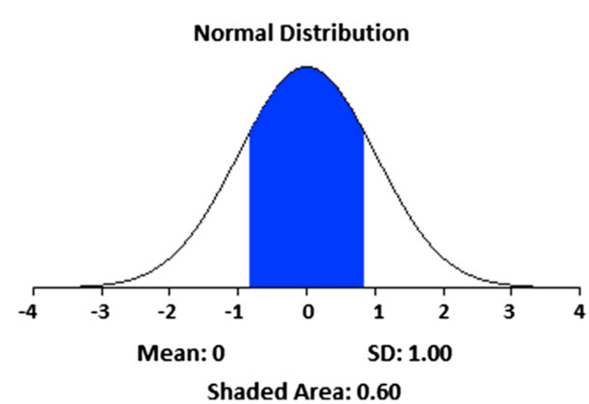


Fig. 4. Seat height accommodation.

growth charts are based on the Stature-for-age and Weight-for-age percentiles (See Figs. 5 and 6).

4.2. Population accommodation guidelines

In order to design the classroom furniture that would accommodate a larger population sample (90% of the population of first graders in the United States), regression equations (5)–(10) were used for the furniture design limits, taking into consideration the assumptions made and the necessary constraints. Since adjustability is incorporated, then the accommodation range is assumed to be from 5th–95th percentile. This means the design intends to fit 90% of the entire population of first graders in the United States. Using the growth charts in Figs. 5 and 6, the percentile range and the following values were obtained as shown in Table 2.

4.2.1. BMI-for-age calculation

The traditional method of BMI calculation was used to determine the BMI-values for the 5th to 95th percentile first graders. The 5th percentile weight was computed and divided by the square of

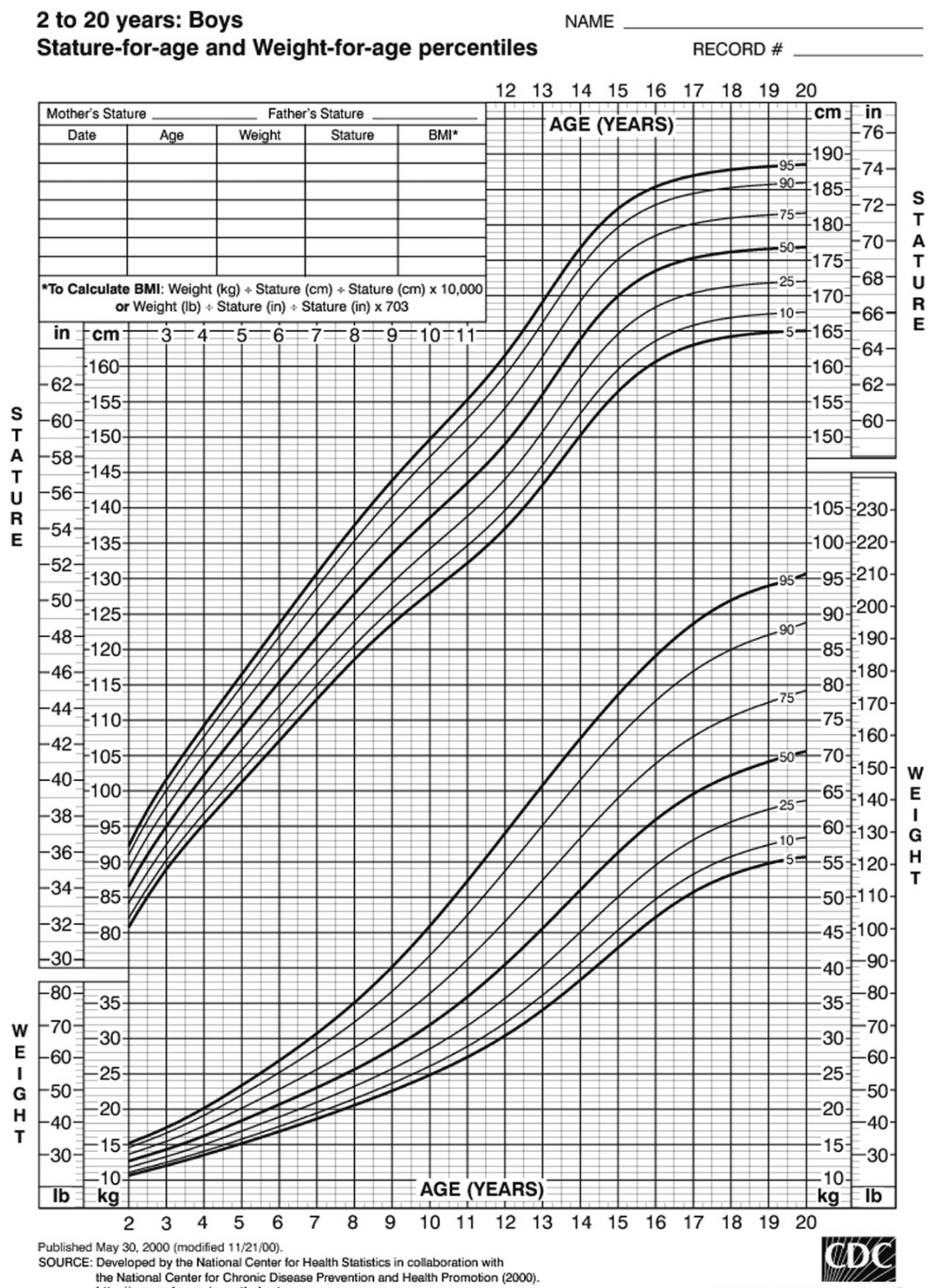


Fig. 5. Growth Chart: Stature-for-age and Weight-for-age Percentiles (Boys 2–20 years).

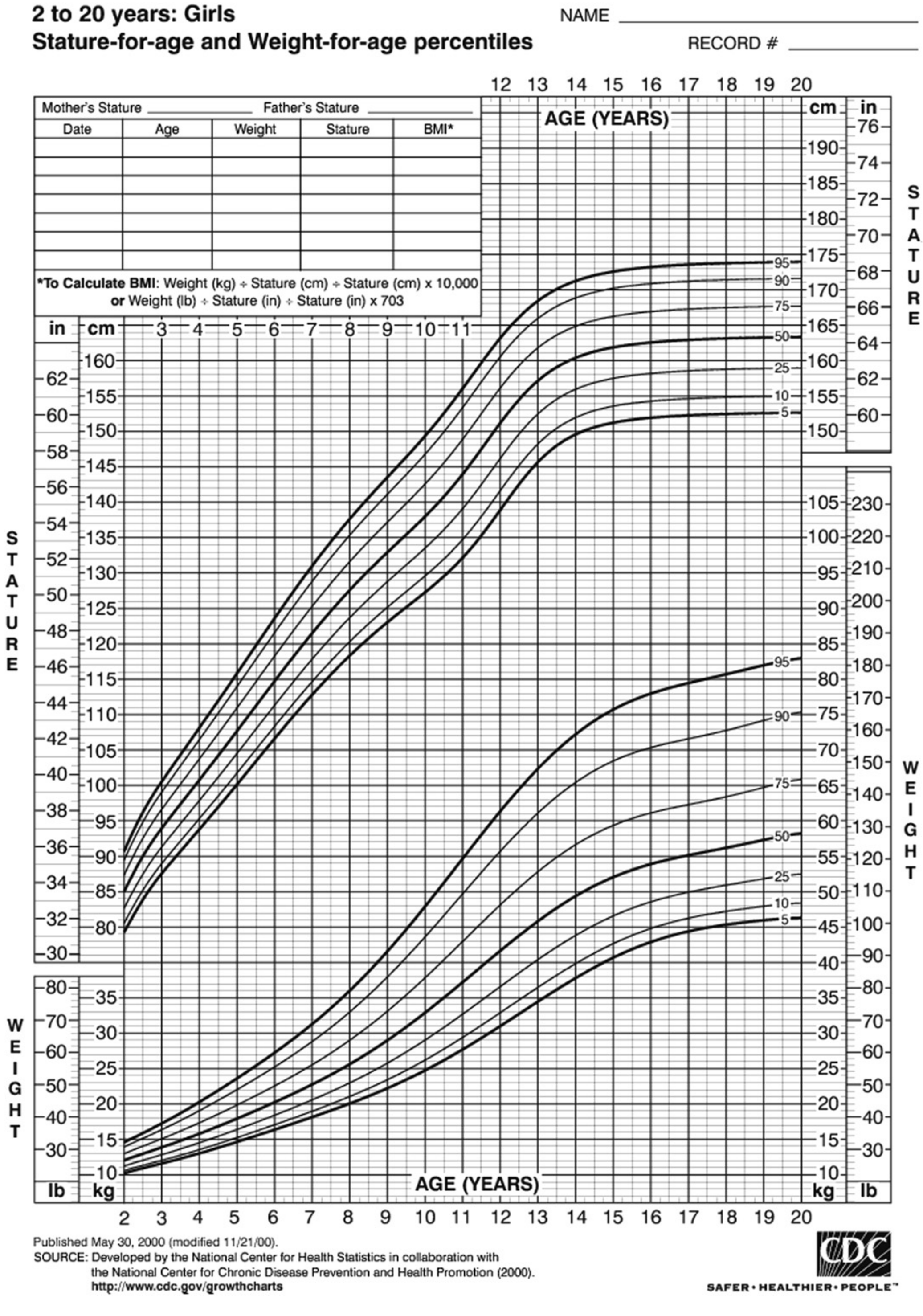


Fig. 6. Growth Chart: Stature-for-age and Weight-for-age Percentiles (Girls 2–20 years).

the 5th percentile stature. This was done for all the age range, gender and percentiles. The derived BMI-for-age computation is shown in Table 3.

4.2.2. Accommodation limits

The accommodation limits could be obtained by using the values for the growth charts in Figs. 5 and 6. The obtained chart values for the respective percentiles were then incorporated into the regression equations (5)–(10) in order to determine the dimensions limits of the classroom furniture. From Table 2 above (although not very significant), in terms of stature, the 5th percentile 6 year old male value (105.41 cm) is lesser than the 5th percentile 6 year old female (106.68 cm). For the 95th percentile values for 6 year old children; the male value for stature (124.46 cm) is slightly higher than that of the 95th percentile 6 year old female (123.19 cm). Another major observation is that of the weight limits, the 5th percentile value for 6 year old male (16.33 kg) is slightly higher than the 5th percentile female (15.42 kg).

Table 2
Growth chart values for 1st graders.

Percentile		5th	10th	25th	50th	75th	90th	95th
Stature-for-age (cm)								
Boys	6 years	105.41	107.95	111.76	115.57	118.11	120.65	124.46
	7 years	113.03	115.57	118.11	121.92	125.73	128.27	130.81
Weight-for-age (kg)								
Boys	6 years	16.33	17.24	18.60	20.41	21.77	24.49	27.22
	7 years	18.14	19.05	20.87	22.68	25.40	28.12	30.84
Stature-for-age (cm)								
Girls	6 years	106.68	109.22	111.76	115.57	118.11	120.65	123.19
	7 years	113.03	115.57	118.11	120.65	125.73	129.54	132.08
Weight-for-age (kg)								
Girls	6 years	15.42	17.24	19.05	20.41	22.68	25.40	27.22
	7 years	18.14	19.05	19.96	22.68	25.40	29.03	30.84

Table 3
BMI-for-age for first graders.

Percentile		5th	10th	25th	50th	75th	90th	95th
BMI-for-age								
Boys	6 years	14.69	14.79	14.88	15.28	15.61	16.83	17.57
	7 years	14.20	14.26	14.956	15.26	16.07	17.09	18.03
Girls	6 years	13.55	14.45	15.25	15.28	16.26	17.45	17.93
	7 years	14.20	14.26	14.31	15.58	16.07	17.30	17.68

However, the 95th percentile values for 6 year old male and 95th percentile female for statue are the same (27.22 kg).

For the 7 year olds, a stature measure for the 5th percentile male (113.03 cm) is the same for the 5th percentile 7 year old female (113.03 cm). For the 95th percentile values for 7 year old children; the male value for stature (130.81 cm) is slightly lesser than that of the 95th percentile 7 year old female (132.08 cm), not a very significant difference. For weight limits, the 5th percentile value for 7 year old male (18.14 kg) is the same for the 5th percentile female. Also, the 95th percentile values for 7 year old male and 95th percentile female for statue are the same (30.84 kg). It should be noted that when accommodating for 90% of the population, the values of the lowest 5th percentile and the values of the highest 95th percentile should be considered for stature and weight. Using the regression equations obtained, the lower limit and the upper limit could be determined. Tables 4–9 show the values obtained when the lowest 5th percentile and the values of the highest 95th percentile should be considered for stature, weight and BMI. The minimum and maximum adjustability ranges to accommodate 90% population of 1st graders are highlighted in Tables 4–9.

Table 4
Recommended dimension for the seat height adjustability range.

Percentile		5th	10th	25th	50th	75th	90th	95th
Popliteal height (cm) – for seat height								
Boys	6 years	25.83	26.44	27.36	28.27	28.88	29.49	30.40
	7 years	27.66	28.27	28.88	29.79	30.71	31.32	31.93
Girls	6 years	26.11	26.75	27.36	28.27	28.88	29.49	30.10
	7 years	27.66	28.27	28.88	29.49	30.71	31.62	32.23

Table 5
Recommended dimension for the seat depth adjustability range.

Percentile		5th	10th	25th	50th	75th	90th	95th
Buttock-popliteal length (cm) – for seat depth								
Boys	6 years	27.41	28.02	28.93	29.87	30.48	31.09	32.03
	7 years	29.24	29.87	30.48	31.39	32.33	32.94	33.55
Girls	6 years	27.71	28.32	28.93	29.87	30.48	31.09	31.70
	7 years	29.24	29.87	30.48	31.09	32.33	33.25	33.86

Table 6
Recommended dimension for the seat width adjustability range.

Percentile		5th	10th	25th	50th	75th	90th	95th
Hip breadth (cm) - for seat width								
Boys	6 years	19.28	19.41	19.51	19.99	20.37	21.84	22.73
	7 years	18.69	18.77	19.61	19.96	20.93	22.17	23.29
Girls	6 years	17.91	19.00	19.96	19.99	21.16	22.61	23.16
	7 years	18.69	18.77	18.82	20.35	20.93	22.40	22.86

Table 7
Recommended dimension for the back rest adjustability range.

Percentile		5th	10th	25th	50th	75th	90th	95th
Shoulder height – for back rest								
Boys	6 years	35.64	36.47	37.72	38.96	39.80	40.61	41.86
	7 years	38.13	38.96	39.80	41.05	42.29	43.13	43.94
Girls	6 years	36.04	36.88	37.72	38.96	39.80	40.61	41.45
	7 years	38.13	38.96	39.80	40.61	42.29	43.54	44.37

Table 8
Recommended dimension for the arm rest adjustability range.

Percentile		5th	10th	25th	50th	75th	90th	95th
Elbow height – for arm rest								
Boys	6 years	16.28	16.71	17.32	17.96	18.36	18.80	19.43
	7 years	17.55	17.96	18.36	19.00	19.63	20.04	20.47
Girls	6 years	16.48	16.92	17.32	17.96	18.36	18.80	19.20
	7 years	17.55	17.96	18.36	18.80	19.63	20.27	20.68

Table 9
Recommended dimension for the desk height adjustability range.

Percentile		5th	10th	25th	50th	75th	90th	95th
Knee height – for desk height								
Boys	6 years	30.12	30.86	31.98	33.07	33.81	34.54	35.66
	7 years	32.33	33.07	33.81	34.93	36.02	36.75	37.49
Girls	6 years	30.51	31.24	31.98	33.07	33.81	34.54	35.28
	7 years	32.33	33.07	33.81	34.54	36.02	37.11	37.85

5. Conclusion

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 – chair combination are often the major reasons why children experience some level of discomfort while in the classroom. Initial examination of the existing furniture indicated several anomalies in the design of the classroom benches and desks such as lack of cushion on the hardwood benches, and lack of backrests. Based on several complain of body aches and pains from the children, a survey was conducted to obtain additional information which could be helpful for the research analysis. Findings from the questionnaire showed that a large majority of the 126 first graders surveyed (95%) attended classes more than three times a week and were seated in the classroom for more than four hours daily (93%). Also, 58% of the children acknowledged they had been absent from school at least once in a month due to aches and pains often associated with their sitting postures while in the classroom.

In summary, this paper analyzed anthropometric information obtained from the subjects to provide adequate guidelines for the design of adjustable classroom furniture. This was based on the need to reduce the level of mismatch between the first graders and the type of furniture provided for their use. One of the major objectives of this research was to propose ergonomic design guideline for classroom furniture that would accommodate at least 90% of the entire population of elementary school first graders in the United States. Values from relevant growth charts which comprises of stature-for-age and weight-for-age percentiles limits for boys and girls of ages 2 to 20 years old was obtained and incorporated into anthropometric equations (see Equations (5)–(10)) in the quest of obtaining adjustability ranges for the classroom furniture. In order to accommodate at least 90% of the population of first graders, the following dimensions obtained from Tables 4–9 are recommended (based on a recommended clearance of ± 1 to 2 cm): For seat height (25.83–32.23 cm); seat depth (27.41–33.86 cm); seat width (17.91–23.29 cm); back rest (35.64–44.37 cm); arm rest (16.28–20.68 cm); and desk height (30.12–37.85 cm).

Based on the recommended dimensions of the elementary school furniture design for first graders, it will be easier to produce adjustable ergonomics-oriented classroom furniture within the recommended design limits. Even though adjustability could increase the cost of production, a major benefit of incorporating adjustability into the furniture design is the opportunity to increase the accommodation limits. Based on the variability in the body sizes and dimensions of the students, individual classroom furniture for the children is recommended, as this would provide the opportunity for each of the children to adjust their desk/workstation based on their preference or comfort level. This will ultimately enable the reduction of the severity rate of pains and aches experienced by the children.

5.1. Future work and limitations of the study

Further evaluations would incorporate additional anthropometric data from other age groups of young elementary school students, from different parts of the world, with more gender mix in the experimental design. More gender mix and other individual differences such as race, age, and more data from multiple elementary schools would have also improved the quality of the experiment. In the future, a comparison of the results obtained in this analysis and the data obtained from ISO 5970 – 1979 and the New British and European Educational Furniture Standard (EN 1729). Although the results of this experimental study show that stature is a good predictor of a number of other body dimensions such as popliteal height, elbow height, etc, efforts could be made to determine other possible predictors such as weight or BMI. In terms of the hip breath, the body weight could have also been analyzed as a possible predictor and the relationship obtained could have been used to compare to that obtained when the BMI was used.

Although this study proposed classroom furniture design guidelines to accommodate approximately 90% of the population of first graders in the United States, significant increase in the overall accommodation could have been obtained if further analysis was conducted to investigate the possibility of increasing the height adjustability limits. This would have further provided accommodation for extreme individuals within the population. This design recommended adjustability for all the dimensions of the classroom furniture. Incorporating too much adjustability could be extremely costly which could lead to a difficulty in affordability. The accuracy of the experiment would have also been improved if the number of experimental subjects had been increased.

References

Balague, F., Dutoit, G., Waldburger, M., 1988. Low back pain in schoolchildren. An epidemiological study. Scand J. Rehabil. Med. 20 (4), 175–179.

Bendix, T., 1987. Adjustment of the seated workplace—with special reference to heights and inclinations of seat and table. Dan. Med. Bull. 34 (3), 125–139.

Branton, P., 1969. Behavior, body dynamics and discomfort. Ergonomics 12, 316–327.

British Standard Institute, 2007. Furniture. Chairs and Tables for Educational Institutions. Functional Dimensions (BS EN 1729-1:2006). CEN Publishers, ISBN 978 0580 49922 7.

Brunswic, M., 1984. Ergonomics of seat design. Physiotherapy 70 (2), 40–43.

Burgess-Limerick, R., Plooy, A., Ankrum, D., 1999. The influence of computer display height on head and neck posture. Int. J. Ind. Ergon. 23, 171–179.

Chaffin, D.B., Andersson, G.B., Martin, B., 2006. Occupational Biomechanics, 4th ed. John Wiley & Sons, Inc, New York. New York: Wiley.

Clauser, C.E., Tebbetts, I.O., Bradtmiller, B., McConville, J.T., Gordon, C.C., 1988. Measurer's Handbook: US Army Anthropometric Survey (ANSUR) 1987–1988, Technical Report NATICK/TR-88/043.

Cook, C.J., Kothiyal, K., 1998. Influence of mouse position on muscular activity in the neck, shoulder and arm in computer users. Appl. Ergon. 29 (6), 439–443.

Cranz, G., 1998. The Chair: Rethinking Culture, Body, and Design, 1st ed. W.W. Norton, New York.

Dillon, J., 1976. School furniture: standing and sitting postures, Building Bulletin DES. HMSO, London. In: Knight, G., Noyes, J., 1999. Children's behaviour and design of school furniture. Ergonomics, 1999, 42, 5, 747–760.

Drummond, D.S., Narechania, R., Rosenthal, A., et al., 1982. A study of pressure distributions measured during balanced and unbalanced sitting. J. Bone Joint Surg. 64A, 1034–1039.

Evans, O., Collins, B., Stewart, A., 1992. Is school furniture responsible for student seating discomfort? In: Hoffean, E., Evans, O. (Eds.), Proceedings of the 28th Annual Conference of the Ergonomics Society of Australia 'Unlocking Potential for the Future Productivity and Quality of Life', Melbourne. Ergonomics Society of Australia, Australia, pp. 31–37.

Evans, W.A., Courtney, A.J., Fok, K.F., 1988. The design of school furniture for Hong Kong school children: an anthropometric case study design. Ergonomics 33, 1511–1521.

Fiell, C., Fiell, P., 1993. Modern chairs. Benedikt Taschen, Kèoln.

Figueroa-Colon, R., Franklin, F.A., Lee, J.Y., Aldridge, R., Alexander, L., 1997. Prevalence of obesity with increased blood pressure in elementary school-aged children. South. Med. J. 90 (8).

Gouvali, M.K., Boudolosa, K., 2006. Match between school furniture dimensions and children's anthropometry. Appl. Ergon. 37 (6), 765–773.

Harris, C., Straker, L., 2000. Survey of physical ergonomics issues associated with school childrens' use of laptop computers. Int. J. Indus. Ergon. 26 (2), 337–347. IJIEchildlap2000.pdf.

Hui Zhu, Eva Haviarova, Stus, Carl A. Eckelman, 1998. School Furniture in Developing Countries. Dept. of Forestry and Natural Resources, Purdue Univ., W. Lafayette, Ind., USA. Technical report.

ISO 5970, 1979. Furniture, Chairs and Tables for Educational Institutions – Functional Sizes. International Standards Organization (ISO), Geneva, Switzerland. UDC 371.63.

Jackson-Leach, R., Lobstein, T., 2006. Estimated burden of paediatric obesity and co-morbidities in Europe. Part 1. The increase in the prevalence of child obesity in Europe is itself increasing. Int. J. Pediat. Obes. 1 (1), 26–32.

Jeong, B.Y., Park, K.S., 1990 Dec. Sex differences in anthropometry for school furniture design. Ergonomics 33 (12), 1511–1521.

Jung, H.S., 2005. A prototype of an adjustable table and an adjustable chair for schools. Int. J. Indus. Ergon. 35 (10), 955–969.

Karvonen, M.J., Koskela, A., Noro, L., 1962. Preliminary report on the sitting postures of school children. Ergonomics 5, 471–477. In: Knight, G., Noyes, J., 1999.Children's behaviour and design of school furniture. Ergonomics, 42, 5, 747–760.

Knight, G., Noyes, J., 1999. Children's behaviour and design of school furniture. Ergonomics 42 (5), 747–760.

Kumar, S., 1994. A computer desk for bifocal lens wearers, with special emphasis on selected telecommunication tasks. Ergonomics 37, 1669–1678.

Laeser, K., Maxwell, L., Hedge, A., 1998. The effect of computer workstation design on student posture. J. Res. Comput. Educat. 31, 173–188.

Laville, A., 1985. Postural stress in high-speed precision work. Ergonomics 28, 229–236.

Linton, S.J., Hellsing, A.L., Halme, T., Akerstedt, K., 1994. The effects of ergonomically designed school furniture on pupils' attitudes, symptoms and behaviour. Appl. Ergon. 25, 299–304.

Lueder, R., Rice, V., 2007. Physical development in children and adolescents and age related risks. In: Lueder, R., Berg Rice, V.J. (Eds.), Ergonomics for Children: Designing Products and Places for Toddler to Teens (499–507). Taylor & Francis, New York.

Mandal, A., 1981. The seated man (Homo Sedens), the seated work position, theory and practice. Appl. Ergon. 12, 16–19.

Mandal, A.C., 1985. The Seated Man: Homo Sedens. Dafnia Publications, Klampenborg, Denmark.

Melzer, J.E., Moffitt, K.W., 1997. Head-Mounted Displays: Designing for the User. McGraw Hill, New York, NY.

Miller, H., 2000. Workplace research. Source: http://www.hermanmiller.com/research/.

Mokdad, M., Al-Ansari, M., 2009. Anthropometrics for the design of Bahraini school furniture. Int. J. Indus. Ergon. 39 (5), 728–735.
Nag, P.K., Pala, S., Kotadiyaa, S.M., Naga, A., Gosaia, K., 2008. Human–seat interface analysis of upper and lower body weight distribution. Int. J. Indus. Ergon. 38 (5–6), 539–545.
Niemi, S.M., Levoska, S., Rekola, K.E., et al., 1997. Neck and shoulder symptoms of high school students and associated psychosocial factors. J. Adolescent Health 20, 238–242.
Olsen, T.L., Anderson, R.L., Dearwater, S.R., Kriska, A.M., Cauley, J.A., Aaron, D.J., LaPorte, R.E., 1992. The epidemiology of low back pain in an adolescent population. Am. J. Pub. Health 82 (4), 606–608.
Panagiotopoulou, G., Christoulas, K., Papanckolaou, A., Mandroukas, K., 2004. Classroom furniture dimensions and anthropometric measures in primary school. Appl. Ergon. 35 (2), 121–128.
Parcells, C., Stommel, M., Hubbard, R.P., 1999. Mismatch of classroom furniture and student body dimensions. J. Adolescent Health 24, 265–273.
Pheasant, S., 1998. Body Space. Anthropometry, Ergonomics and the Design of Work, second ed. Taylor & Francis, p. 3–83.
Ready, D., Lee, V., Welner, K., 2004. Educational equity and school structure: school size, overcrowding, and schools-within-schools. The teachers college record. Source: http://www.tcrecord.org.
Roebuck, John A., Kroemer, K.H.E., Thomson, Walter Gary, 1975. Engineering Anthropometry Methods. John Wiley and Sons, New York, NY.
Rumberger, R.W., 2002. Student mobility and academic achievement. ERIC Digest, EDO-PS-02-1. Source: http://www.education.ucsb.edu.
Saarnia, L., Nygarda, C., Nummic, T., Kaukiainend, A., Rimpelaa, A., 2009. Comparing the effects of two school workstations on spine positions and mobility, and opinions on the workstations – a 2-year controlled intervention. Int. J. Indus. Ergon. 39 (6), 981–987.
Salminen, J.J., 1984. The adolescent back. A field survey of 370 Finnish school children. Acta Paediat. Scand. 73 (Suppl. 315), 1–122.
Shackel, B., Chidsey, K.D., Shipley, P., 1976. The Assessment of Chair Comfort. In: Grandjean, E. (Ed.), Sitting Posture. Taylor & Francis, London, p. 189.
Storr-Paulsen, A., Aagaard-Hansen, J., 1994. The working positions of school children. Appl. Ergon. 25, 63–64.
Tichauer, E., 1978. The Biomechanical Basis of Ergonomics: Anatomy Applied to the Design of Work Situations. Wiley, New York. In: Parcells, C., Stommel, M., Hubbard, R.P., 1999. Mismatch of classroom furniture and student body dimensions. Journal of Adolescent Health, 24, 265–273.
Troussier, B., Davoine, P., de Gaudemaris, R., Fauconnier, J., Phelip, X., 1994. Back pain in school children. A study among 1178 pupils. Scand. J. Rehabil. Med. 26 (3), 143–146.
Wall, M., van Riel, M.P., Snijders, C.J., van Wingerden, J.P., 1991. The effect on sitting posture of a desk with a 10-degree inclination for reading and writing. Ergonomics 34 (5), 575–584.
Yeats, B., 1997. Factors that may influence the postural health of school-children. Occupat. Health Indus. Med. 37 (4) 156–156(1).