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Factors that may influence the postural health of schoolchildren (K-12)

Betsey Yeats

15 Hillsdale Road, Arlington, MA 02174, USA

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Abstract

Ergonomic seating and proper positioning during the performance of activities is a major focus in the adult workplace. This focus, however, is typically ignored in classrooms where our youngest workers spend the majority of their time. A review of the literature was done to determine the effects of school furniture design on the postural health of schoolchildren (K-12). The review indicated that the adjustability of school furniture is an important design feature if children are to have equal educational opportunity, increased comfort, and decreased incidences of musculoskeletal symptoms. The effectiveness of ergonomic school furniture on schoolchildren has been demonstrated in only one study reviewed in this paper. The other studies are reviewed in an effort to identify: (1) the variation of anthropometric measures of children; (2) the performance of activities exposing children to various postures; and (3) the physical design features of school furniture as three factors which influence the postural health of schoolchildren. © 1997 Elsevier Science Ireland Ltd.

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1. Introduction

Work means many things to many people and is not limited to regular, paid employment in which many adults engage. 'Work represents a major human performance area that encompasses life roles such as homemaker, employee, volunteer, student, or hobbyist' (Jacobs et al., 1992, p. 1086). In keeping with this concept, schoolchildren (K-12) are workers and their classrooms are their work environments. In 1994 alone, there

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were 66 427 000 students across the United States, of which 81% were enrolled in either nursery school, kindergarten, elementary school, or high school. Over the course of their educational careers, these children will be exposed to a number of classroom environments, which may not support their postural needs during the performance of various classroom activities, putting them at risk for injury.

This review paper is intended to summarize the research concerning the effects of school furniture design on the postural health of schoolchildren. This paper will examine the literature by introducing aspects of sitting posture and by focusing on the following three factors related to school furniture design that influence the posture of schoolchildren: (1) anthropometric measures of schoolchildren; (2) the performance of activities; and (3) the physical design features of school furniture. A computer-indexed and manual investigation into the literature was conducted, yielding a paucity of American studies relating schoolchildren and school furniture design. The studies presented in this paper therefore emanate predominantly from foreign countries such as Sweden, Denmark, and The Netherlands, among others, where the awareness of schoolchildren in their classroom environments appears to be more advanced.

The relationship between an adult worker's anthropometric measures, the physical design features of their workspace and proper positioning during the performance of an activity (i.e. computer use) is significant, evidenced by today's enormous ergonomic focus in the workplace. Driving this focus is prevention and the common belief that proper positioning during the performance of activities in the workplace will not only enhance the productivity of the worker, but decrease the incidence of injury and associated health care costs as well. In the management of today's increasing incidences of musculoskeletal injuries among adult workers, occupational therapy intervention typically includes the following principles of ergonomic and injury prevention techniques: analyzing the work environment; eliminating and minimizing exposure to environmental hazards that predispose injury; educating workers on necessary preventive techniques (Bettencourt, 1995). Because the literature suggests that exposure to improper posture early in life is related to injury in adulthood (Mandal, 1982; Olsen, 1992; Knusel and Jelk, 1994), wouldn't the same principles of ergonomic and injury prevention apply to schoolchildren as they do to the adult population? Occupational therapy practitioners can play an important role, not only in minimizing the hazards that exist in the classroom, but also in educating students on prevention and the importance and techniques of proper postural care.

Throughout the years, chairs have become readily recognized in connection with both school and work environments. The history of the chair is believed to have its origin nearly 5000 years ago when leaders and chiefs sat on thrones and chairs as a sign of dignity, with the others sitting on the ground (Grismsrud, 1990). The traditional sitting position with straight backs and 90° angles at the hips, knees, and ankles, is believed to be an inherited phenomenon as well, passed down through many generations (Grimsrud, 1990). In the late 1800s, Staffel of Germany designed school furniture using the straight angles dictated by the traditional sitting position, which became the post-war model for school furniture in general (Grimsrud, 1990).

As the class society developed from the disorganized Nomadic Society, people were taught to sit in a static position; on church benches, in town halls, etc. Nomadic man was pulled down off his horse and forced into a chair or onto a bench. Even today we sit in the same type of chairs which were designed several thousand years ago; static, stiff and at the wrong angles: a destructive combination (Grimsrud, 1990, p. 291).

Today the sitting position is commonly adopted and with it comes associated postural health risks. Static postures and prolonged sitting are two identified risk factors for lower back pain (Kumar and Mital, 1992). Static work, characterized by slow contractions with heavy loads or by long-lasting holding postures, impairs the blood supply and causes waste products to build up in muscles

and produce acute pain (Grandjean and Hunting, 1977). Decreased blood flow to the organs and muscles, characteristic of the traditional sitting position, can decrease the amount of oxygen supplied to the brain causing a person to tire more easily (Grimsrud, 1990). On a more general level, Kumar and Mital (1992) report that biological tissues have a finite life, are subject to wear and tear and may have a reduced threshold at which point the tissues will fail if continual stress is placed upon them.

As the role of a student requires schoolchildren to spend approximately 1260 h/year for 12 years in the classroom, often sitting in static positions on hard, uniformly designed classroom furniture, it would appear that they are particularly at risk for maladies associated with poor postural health (Jones, 1981). Good posture in sitting is important in the prevention of injury, yet Wheatley and Hallock (1951) report that good posture is hard to achieve without the support of adjusting chairs, desks and tables in the school environment. Wheatley and Hallock also report that sitting habits are inevitably created early in life and that the object of the adjustable chair and desk in the classroom is to promote natural, comfortable sitting positions early in life so that they will become habitual. Like Wheatley and Hallock, Floyd and Ward (1969) contend that the classroom is the most appropriate place for the habituation of good sitting habits to take place, because bad sitting habits acquired early are most difficult to change later in adulthood.

Freudenthal et al. (1991) indicate that correct sitting posture should include: dynamic behavior with many postural changes, sitting erect most of the time, and leaning back in the chair to rest the back, without strong flexion of the cervical spine. Wheatley and Hallock (1951) described good sitting posture as having the pelvis sit vertically, with the forward lumbar curve preserved, and the shoulders freely hanging back. They further state that 'the points of the seat bones, the crests of the hipbones, and the shoulder tips should be in the same plane, and in this position there should be no uncomfortable pressures, strains, pushes or pulls' (Wheatley and Hallock, 1951, p. 418).

2. Anthropometric measures

In today's classroom, children are repetitively exposed to the hazards of abnormal or awkward posturing due to classroom furniture that's often too big or too small. Because children vary widely in their anthropometric measurements, both across age groups and within the same age groups, all chairs and desks do not fit all children. To achieve a proper fit that promotes proper posture between school furniture and schoolchildren, it is important that the design of school furniture recognize and reflect variations in anthropometric measurements across children of different sizes and different cultures. Oxford (1969), Evan et al. (1988), Jeong and Park (1990), and Ray et al. (1995) all conducted studies which focused on anthropometric measures of children relative to furniture design. The results of each study, however, cannot be generalized to all children, given the variation of anthropometric measures that exist between different cultures.

Data from an anthropometric survey directed by Oxford (1969), measuring over 13000 Australian participants from infancy to adulthood, indicated that girls reach 65% of their stature at age four and 95% at age 13; the same data indicated that boys reach 60% of their stature at age four and 95% at age 15. The data demonstrates the tremendous amount of physical growth that takes place during the school years. Also demonstrating the differences in size between schoolchildren of the same grade, Oxford found that of 578 kindergarten children, 10% had a lower leg measurement equal to the mean, while 10% had a seat-to-elbow measurement equal to the mean. Not one child, however, had both of the means and according to Oxford these are the two measurements most related to chair and table heights. According to Oxford, a chair satisfies postural requirements when the height of the seat is equal to the lower-leg measurement and the backrest can be utilized. Since the lower leg measurement varies greatly among schoolchildren, more than one size of school furniture available in each classroom would better satisfy a child's postural and educational needs. Oxford states

that 'when pupils sit on chairs that are too low, there is a marked tendency for them to slouch, to push the feet forward and become a nuisance to others, and, generally, to adopt bad postural habits' (Oxford, 1969, p. 153). In addition 'when chairs are too high, pupils are freed to 'perch' on the front of the seat, to sacrifice the comfort of the backrest, to lean on the table, to fidget, and if the table is too high, to sit with arms and elbows in a state of tension' (Oxford, 1969, p. 154). To satisfy the need for more than one size of school furniture in New South Wales, Australia, Oxford reported that six heights of movable chairs and desks have been distributed to their classrooms since the end of World War II.

Evan et al. (1988) took anthropometric measures from 684 normal, healthy primary and secondary Hong Kong Chinese schoolchildren, ages 6–18, and compared them to anthropometric values for Hong Kong children previously published by Chan in 1972. The purpose of their study was to improve the fit between school children and the tables and chairs used in Hong Kong's schools by making design recommendations based on their results. Evan et al.'s increased values for stature suggested a trend of increased size. Evan et al. (1988) reported that because classrooms are organized by age and not anthropometric measures, the furniture must accommodate the range of sizes of pupils in the different classes. Like Oxford (1969), Evan et al. (1988) found rapid growth in children aged 6–14 years old, requiring that four categories of furniture sizes be available to achieve a reasonable fit between the anthropometric measures of children and school furniture; beyond age 14 one category of furniture size was determined to accommodate five secondary forms (3–7). This furniture allocation is suggested to ensure that the great majority of children can work comfortably in good posture. Both Evan et al. and Oxford proposed that discomfort and bad postures associated with badly designed chairs and tables used in schools are factors that may affect academic performance, as well as the physical development of schoolchildren.

Jeong and Park (1990) specifically investigated gender differences and the interrelationships among the anthropometric measurements of Korean school children in order to provide appropriately sized chairs and desks for school use. In total 1248 participants, ages 6–17 years old, participated in their study. There were 52 boys and 52 girls in each age group and all were randomly selected from four elementary, middle and senior high schools in Seoul, Korea. Results of the study indicated that between the ages of 10 and 11, the mean height of the girls exceeded the mean height of the boys. According to Jeong and Park boys above 126 cm require higher desk and chair heights than girls of same stature, due to their relatively higher buttock–popliteal length and elbow to floor distance. In addition, girls above 120 cm require a larger seat depth and breadth of chair than boys of the same stature, due to their relatively higher buttock–popliteal length and hip breadth than boys of the same stature. Jeong and Park concluded that boys and girls have different requirements for the design of their work space, including the classroom. In addition Jeong and Park suggested that these results highlighted the important relationship between body dimensions and stature, citing the usefulness of this relationship in estimating unknown body dimensions when designing school furniture. Jeong and Park attributed a reduction of anthropometric measurements between age bands to differences in socioeconomic stratum, however, they did not substantiate this proposed relationship.

Ray et al. (1995) also reported that the dimensions of the chair should have reasonable agreement with the user's physical dimensions. They conducted a study which focused on 81 anthropometric measures of 198 kindergartners from India, ages 3–5, specifically citing a lack of data for this age range. Results indicated that the majority of the vertical dimensions have a higher correlation with stature than weight, while the horizontal and circumference measures have a higher correlation with weight than stature. Like Jeong and Park (1990), Ray et al. (1995) recommended that the means of the ratio's of each segmental length to stature be used to determine different body dimensions of other children in a particular age group when stature or body weight is unknown. In general the authors report that these data will provide Indian designers with some basic guide-

lines for the development of products or work environments of children aged between three and five.

Results from studies conducted by Oxford (1969), Evan et al. (1988), Jeong and Park (1990), and Ray et al. (1995) all support the need for adjustability or incrementally sized school furniture in classrooms to accommodate the variation in anthropometric measures across different age groups, within the same age groups, and between genders. Both Jeong and Park and Ray et al. cited the importance of the relationship between body dimensions and stature and the usefulness of this relationship in estimating unknown body dimensions when designing school furniture. A proper fit between schoolchildren and school furniture is an important aspect of attaining good posture and one that deserves attention if all children are to be given equal academic opportunity (Oxford, 1969).

3. Performance of activities

In addition to a poor fit between the anthropometric measures of schoolchildren and school furniture, the performance of classroom activities such as reading and writing often place the student in abnormal or awkward posturing with the use of stationary classroom furniture. Both Floyd and Ward (1969) and Storr-Paulsen and Aagaard-Hansen (1994) identified typical positions of schoolchildren during the performance of classroom activities, in addition to the corresponding amount of time spent in these positions.

Storr-Paulsen and Aagaard Hensen (1994) conducted a survey in Denmark, asking teachers to record various working positions of 194 schoolchildren ages 5–15 for a 1-week period. The study focused specifically on the priorities of the teachers and their time schedules relative to factors that ergonomically constrain schoolchildren. For each lesson, both the subject and the types of working postures that the teacher expected the class to assume during the lesson were recorded. The results indicated that the children in pre-school were expected to be physically active for 73% of the total time, while the ninth formers were expected to be active for 19% of the total time. Also during a 90-min morning lesson, the teachers wanted the pre-schoolers to work in a seated posture without interruption for 19 min, the ninth formers for 90 min, and the 3rd, 7th, 8th and 9th formers for an average 60 min. In addition 43% of the total seated time was spent in backward-leaning activities, while the other 57% was spent leaning forward, reading or writing. In addition to reporting from both a medical and educational viewpoint that it is not beneficial to be seated for more than 45 min without breaks, Storr-Paulsen and Aagaard-Hensen also proposed that the effects of time scheduling and the organization of teaching be taken into consideration when evaluating school ergonomics.

Floyd and Ward (1969), like Storr-Paulsen and Aagaard-Hensen (1994) addressed the same issue of task performance while seated, however, they focused on direct observations of children without consideration for the teachers scheduling and organization. Both the amount of time spent performing certain tasks and the proportions of time that postural behaviors were observed to occur in parallel with these activities were recorded for 84 participants with a mean age of 17.2 years. The subjects were observed at their usual desks and chairs during 20–24 lesson periods. Results suggested that: listening was observed to occupy between 35 and 40% of the total time; writing occupied nearly 30% of the time; following a text or reading occupied approximately 10–15% of the time; the other activities of reading, looking up, speaking, preparing for class, reaching for contents of satchel, coat or desk, standing up and sitting down, and being absent temporarily from the classroom took up the remaining 15–25% of time. The following three postures were observed to occur most frequently in parallel with the aforementioned activities: sitting without support from the backrest (approx. 77% of the time); the trunk inclined forwards (approx. 72% of the time); leaning forward on the desk with both arms supported on the desk (approx. 65–80% of the time). Floyd and Ward concluded that although the activity of writing occupied 30% of the student's time, leaning forward on the desk with both arms supported occurred nearly 65–80% of the time, indicating that this position is assumed even when

the constraints of writing do not require it. The authors also concluded from their analysis that the use of the backrest was observed most often in positions when only one arm or no arms were resting on the desk.

As part of the same study Floyd and Ward (1969) conducted a pilot electromyographic investigation with one participant of the same age and stature as the 84 participants previously mentioned. The purpose of the electromyographic study was to obtain recordings of simultaneous bilateral muscle activity of the trunk, including the cervical portion and the mid-clavicular portion of the trapezius muscle, the post-axillary folds of the latissimus dorsi muscle and the lumbar region of the erector spinae muscles in three symmetrical and three non-symmetrical seated postures. The symmetrical postures and their respective electromyographic results included: (1) sitting at attention without use of the backrest, with legs bent at a right angle at the knee and with the arms relaxed in the lap, showed an increase in activity of the erector spinae muscles; (2) sitting erect comfortably with use of the backrest, with the trunk slightly rounded, with legs bent at a right angle at the knee and arms relaxed in the lap, showed almost minimum activity in all four muscle groups; and (3) sitting with the body supported by the arms leaning upon the desk and the trunk in a forward relaxed position showed an increase in activity of the left and right latissimus dorsi muscles (larger than that of the erector spinae muscles in posture 1), as well as an increase in the left and right cervical portions of the trapezius muscle, but to a lesser extent. The asymmetrical postures and their respective electromyographic results included: (1) sitting erect comfortably with the right arm only supported on the desk showed an increase in the right latissimus dorsi and erector spinae muscles particularly, as well as an increase in the mid-clavicular portion of the trapezius muscle; (2) sitting erect comfortably with the left arm only supported on the desk showed the reverse, with an increase in the left latissimus dorsi and erector spinae muscles, as well as an increase in the mid-clavicular portion of the trapezius; and (3) sitting in the habitual left-handed position for writing at the desk showed an increase in activity for all muscles, except for the left erector spinae muscle. Floyd and Ward reported that the marked increase in the latissimus dorsi muscles on the side opposite the moving limb, were a result of those muscles actively supporting the trunk against gravity. Floyd and Ward also concluded that the symmetrical position of leaning forward with both arms supported by desk provoked activity in the latissimus dorsi and the cervical portion of the trapezius, indicating that this position is not necessarily a position of rest.

Floyd and Ward (1969) recommended further studies using electromyography; they also proposed that further analysis of postural behaviors, coupled with the basic anthropometric requirements, be considered in the design of both seats and chairs. The results of the electromyographic portion of the study should be viewed with caution as only one participant participated. In addition, the study looks at postural behaviors across all of the activities together and therefore certain postures cannot be correlated specifically to certain activities.

Floyd and Ward (1969) and Storr-Paulsen and Aagaard Hensen (1994) both identified positions assumed by schoolchildren during the performance of classroom activities. Storr-Paulsen and Aagaard Hensen found that as children advance in grade, the amount of time they're expected to sit without interruption also increased, beyond what they considered to be a healthy amount of time without a break. Storr-Paulsen and Aagaard Hensen also reported that 57% of the total time seated was spent leaning forward, which according to Jeong and Park (1990) is a position that requires increased muscle activity, as compared to sitting against a backrest. Like Storr-Paulsen and Aagaard Hensen, Floyd and Ward found that participants in their study typically sat (1) without support from the backrest; (2) with the trunk inclined forwards; and (3) leaning forward on the desk with both arms supported on the desk while listening, writing, following a text, reading, looking up, speaking, preparing for class, etc.

Results of Floyd and Ward's electromyographic study, however, found that the position requiring the least amount of active contraction from the

four identified muscle groups was sitting erect comfortably using the backrest with the trunk slightly rounded, with the legs bent at 90° at the knee, and the arms relaxed in the lap. This is also the position described by Wheatley and Hallock (1951) as typifying good posture and the position described by Freudenthal et al. (1991) as a good position of rest. Because participants in both studies were typically found leaning forward without use of the backrest for a majority of the time, their postural health may be at risk due to static contractions and prolonged postures, taxing more muscles over longer periods of the time. With adjustability and variability features built into the design of school furniture, however, children could proactively arrange their desks and chairs to fit both their physical needs and their preferences during the performance of activities.

4. Classroom furniture design features

In addition to anthropometric measures and the performance of classroom activities, the physical features of school furniture design can also influence posture. In motor learning literature it is commonly understood that the regulatory features of the environment control features of one's movement; the physical characteristics of a chair and desk in a classroom, for instance, dictate the way in which a student must position him or herself when sitting in a chair or writing at a desk (Gentile, 1987). Hira (1980), Mandal (1982), Freudenthal et al. (1991) and Aagaard-Hansen and Storr-Paulsen (1995), and all conducted studies investigating the preferred features of school furniture design and proposed subsequent recommendations.

Mandal (1982) conducted an empirical field study with the purpose of determining the heights at which 80 participants, ages 7–50, preferred their desks and chairs. If the majority of the participants were adults, however, Mandal's recommendations would not necessarily be generalizable to children. The experiments were conducted using a hydraulic chair and hydraulic table, both originally set in accordance with the standards outlined by the International Standards Organization (ISO) relative to height, at 30–50 cm for the chair and 50–70 cm for the table. In addition the chair was tilted backward 5° and the table top was oriented horizontally. The subjects were asked twice to adjust the height of both the chair and table to the heights they most preferred. Results of the study suggested that the participants preferred both the table and chair heights be 15–24 cm higher than the ISO standards. As a general rule, Mandal recommended that a chair be at least one-third the height of the person using it, while a desk be at least one-half the height of the person using it. Mandal concluded that the study's participants clearly demonstrated their preferences to sit much higher and he further recommended that the seat of the chair slope forward 10–15° with a fixed cushion to counteract sliding forward and that the table top slope backward 10–15°. It is unclear in the study, however, as to whether the recommendations for a sloped chair and sloped table were based on preferences set by the participants or if they were preset and then accepted by the participants. In general Mandal reported that students are a captive audience upon which to conduct seating studies, because of their: (1) short focal distance of approximately 30 cm, compared to an adult's focal distance of 50–70 cm due to presbyopia; (2) their flexible backs; and (3) the demands of the classroom keeping them uniformly focused on the same task. Mandal explains that:

> In order for a person 180 cm tall to position the eyes at a distance of 30 cm from a book placed on a table 70 cm high, the back will have to bend at an angle of 75° if all of the bending takes place in the lumbar joint. On the other hand, if the table is 90 cm high, 50° of flexion will be adequate. If the table is tilted, the flexion can practically be eliminated, as the book is then brought closer and at a better angle to the eyes (Mandal, 1982, p. 263).

In summary Mandal suggests that the 'abuse of children's backs during adolescence could well be the reason for the rapidly increasing number of back ailments' (Mandal, 1982, p. 268). He states that 'designers of furniture have learned nothing about the anatomy of the seated person, and local school authorities seem to place high priority on low-cost furniture that is easily stacked and compactly stored' (Mandal, 1982, p. 268). While high-

lighting important design features, Mandal's seating study appeared to make extensive conclusions based on short 4 or 5 min observations, raising the question of how seating preferences may have changed over time.

In a comparative rating study between three different kinds of furniture, Aagaard-Hansen and Storr-Paulsen (1995), like Mandal (1982), reported that students preferred increased table heights, in addition to other identified design features. The study evaluated three different kinds of school furniture, based on the subjective comfort level of 144 participants between the ages of 7 and 11, in their natural life environment. The participants were systematically divided into three groups. In Phase 1 each group received identical furniture based on the ISO standards. In Phase 2 each group received either: (1) newly made furniture identical to that used in Phase 1; (2) newly made furniture based on Mandal's recommendations with the desk approximately 15 cm higher than the furniture used in Phase 1, a forward slanting seat and the angle of the desk top adjustable between 0 and 20°; the desk height was also adjustable to suit the preferences of the students; or (3) newly made furniture marginally higher than the furniture used in Phase 1, with its seat slanted forward by 3° and the angle of the desk top adjustable. Results suggested that participants considered all three types of new furniture better than the original furniture used in Phase 1. Results also suggested that the type (2) furniture, with a forward sloping seat, tiltable desk-top between 0 and 20°, and a desk height 15 cm higher, was considered significantly better than types (1) and (3) in a global comparison between the new and old furniture, back-rest, reading position, table height, and chair height. Findings for both furniture types (2) and (3), relative to the adjustable desk-top feature, were nearly identical with scores of 93.9 and 93.2 respectively, supporting the student's interest in this feature regardless of the type of furniture being used. An interesting finding also revealed that 43 of the 144 students surveyed in Phase 2 experienced frequent back pain. Aagard-Hansen and Storr-Paulsen concluded that furniture type (2) was preferred for its back-rest, chair height and table height, especially in the reading position. The authors also suggested that these results be considered by school authorities and their medical advisors, when choosing school furniture. The author's believe that the back health of school children is a field that involves many disciplines and that the focus on school furniture should be only one aspect of its management.

In addition to both Mandal (1982) and Aagaard-Hansen and Storr-Paulsen (1995), Hira (1980) also found that the table height, among certain other features of both the desk and chair, is an important factor in seating design. Hira conducted a survey to ergonomically evaluate the most commonly used type of fixed educational desk. Approximately 30 lecture halls in colleges and the University of Ludhiana in India were surveyed, collecting characteristic dimensions of a representative group of 14 desks. The relevant characteristics studied included: desk height front edge, desk height rear edge, top horizontal width, top inclined width, slope, seat desk clearance, seat height, seat depth, back rest width, seat back rest clearance.

Hira (1980) applied the established standards found in a thorough literature search whenever possible. However, when not possible, he conducted experiments using 40 participants to determine suitable values. When students outside of the identified participant group were found working naturally at their desks, however, they were also observed. Hira's study resulted in the following recommendations for fixed furniture design: a seat height clearance of 16 cm; a desk height of 73 cm; a table top slope of 12.14° with a S.D. of 2.7°; a writing surface width of 50 cm; a seat height of 44.5–52 cm; a seat depth of 35–38.5 cm for work seats and 23–33 cm for educational desks; a horizontal seat with a slight curve at the front edge to relieve pressure on the thighs; and a back rest with adjustable and sliding seat with cushion to promote comfort and assist in learning.

Hira (1980) emphasized that the application of ergonomics to fixed seating is very limited and that more work is needed. For the many studies conducted, Hira provided a summary of the results and did not include actual data or scores,

upon which he based his recommendations. In addition, participants for the study were selected to be representative of the students of Punjab, India limiting the generalizability of the results to children, due to both age and the variations of anthropometric measures across cultures. Hira proposed that the recommended features could assist in changing posture over the course of the day, benefiting children by supporting their need for dynamic positioning, potentially improving circulation and spinal alignment, increasing levels of arousal and alertness, as well as decreasing pressure on the diaphragm and abdominal cavity.

Freudenthal et al. (1991) conducted a study at a University in The Netherlands with 10 students and staff members, ages 20–60-years-old. Although the participants were not in the K-12 age range, this study is relevant as it directly addresses the effects on posture of a sloped desk top that was also recommended by Hira (1980), Mandal (1982), and Aagaard-Hansen and Storr-Paulsen (1995), during the performance of reading and writing tasks typical of students. Freudenthal et al. (1991) introduced a 10° inclined office desk and made continuous recordings of position of the head and trunk to determine the effects of the inclined desk on sitting posture while reading and writing. Participants were seated in an adjustable chair at an adjustable table. Results indicated that a significant improvement in sitting posture was found, as more upright posture of the head and trunk was measured, decreasing the static load placed upon the muscles and ligaments. Results also indicated that the average median measure of the posture of the trunk changed approximately 8° more upright for the trunk and 9° more upright for the position of the head; in addition flexion of the cervical spine decreased by about 2°. A decrease in the range of postures in the lateral direction was also found, as was a significant decrease in the range of positions for the head. Freudenthal et al. concluded that this finding did not necessarily indicate fewer movements, but did indicate less extreme movements taking place less often. They suggested that this finding reflects less physiological discomfort while reading and writing with the 10° inclined desk. It was concluded that the improvement in sitting posture by using a 10° inclined desk was evident and that an improvement in workplace design can be attained by using reading and writing desks with a 10° inclination.

Recommendations for classroom furniture design features common to the studies conducted by Hira (1980), Mandal (1982), and Aagaard-Hansen and Storr-Paulsen (1995), include increased table height, increased chair height and an adjustable table top. Freudenthal et al.'s (1991) study specifically evaluated the effects of a 10° sloped desk top with results showing a significant improvement in sitting posture. Aagaard-Hansen and Storr-Paulsen and Hira both recommended the back rest as an important design feature to be included. Mandal recommended a forward seat tilt to promote proper posture in leaning forward by reducing the amount of flexion of the back. Each of the aforementioned design features were preferred by the participants in the above mentioned studies and are recommended as important design features in the promotion of good sitting posture.

It has been found that anthropometric measures, the performance of activities, in addition to specific design features of school furniture are all factors that influence the postural health of school children. It is assumed that chairs and desks in classrooms fit all children, however, adjustability and variability of furniture provided in the classroom is needed to satisfy a child's postural and educational needs. The effectiveness of adjustable, ergonomic seating on schoolchildren, however, has been demonstrated in only one study conducted in Sweden. In 1991 the governing laws in Sweden enforcing regulations for a safe work environment were amended to include and apply to schoolchildren in the classroom. Linton et al. (1994) conducted a two-group design study measuring the effects of ergonomically designed school furniture on comfort, sitting posture and the incidence of musculoskeletal symptoms among schoolchildren. Participants included three classes of 10-year-old schoolchildren in the 4th grade; the control group received traditional furniture with a flat top desk and a detached chair with a straight back and the seat at 90°, while the experimental group received ergonomically designed,

adjustable furniture. The students used the furniture for 6 months. In addition to answering a questionnaire, the students' sitting behavior was observed twice before receiving the furniture, twice after receiving the furniture, and 5 months later at a follow-up session. Results of the observations assessing the presence or absence of identified 'sit behaviors' yielded no significant differences between the groups on any of the behaviors, however, about half of the participants in the experimental group were reported to improve their posture. Linton et al. (1994) conjectured that the noted improvements in posture may be important relative to the measure of musculoskeletal symptoms. Results of the questionnaire indicated that the experimental group had higher comfort ratings after receiving the new furniture, in addition to a significant improvement at the follow-up on ratings of how well they sat. In addition, the experimental group experienced a statistically significant reduction in back pain at the follow-up session, while an overall index of back, neck, headache and tiredness together approached statistical significance. There were no differences, however, reported between the groups regarding their awareness of the school work environment. Linton et al. proposed that comfort, although typically thought of as a 'soft' variable, may have an important relationship with schoolchildren complying to advice on posture. Linton et al. states that 'it is unlikely that pupils will be persuaded to use correct postures in order to avoid back pain sometime in the future as an adult: it is more likely that the immediate effects of comfort may be more effective in ensuring that advice about posture is followed' (Linton et al., 1995, p. 304). Linton et al. considered the number of participants reporting musculoskeletal problems to be high but in keeping with other reports. In addition they state that the need for prevention is clear, as 'youngsters are aware of musculoskeletal problems early on and these symptoms appear to be very real and relevant to them' (Linton et al., 1994, p. 304) Linton et al. questioned if the level of significance of the results were masked due to inadequate measures. Also as a result of this study, Linton et al. concluded that providing ergonomic furniture alone is not enough and that proper educational instruction is also required to introduce ergonomics and to teach the students and teachers how to properly adjust the furniture. Linton et al. encouraged additional prospective, controlled studies.

Based on a review of the literature, the design of school furniture does have an effect on the postural health of schoolchildren. Because the physical design features of school furniture require schoolchildren of varying shapes and sizes to fit into uniformly sized chairs and desks, good posture is often sacrificed. Instead poor postures are often assumed, putting at risk both the physical development and academic performance of schoolchildren (Oxford, 1969; Evan et al., 1988). In addition, the standard physical design of school furniture, without adjustability, requires schoolchildren to assume awkward postures during the performance of school activities such as reading and writing. These awkward postures maintained over long periods of time are risk factors for musculoskeletal injury, according to Kumar and Mital (1992). In contrast, adjustable school furniture would not only address the uniqueness of anthropometric measures across schoolchildren, but also support the postural needs of schoolchildren during the performance of school activities. The provision of adjustable school furniture, however, is only part of the solution as Linton et al. (1994) discussed. A unified approach addressing the relationships between the anthropometric measures of schoolchildren, the performance of activities required in the classroom and the physical design features of school furniture is needed to support the postural health of schoolchildren.

Seating has been an important focus in ergonomics and human factors literature on adults. However, little research has been done on the student population and the effects of classroom seating on schoolchildren's postural health. With such widespread adult disability due to musculoskeletal injury, of which improper posture in sitting is a potential contributing factor, it would appear that more research is needed to detect any associations between childhood exposure and adult injury. The studies discussed in this paper were brought together in an effort to highlight

the need for proactive prevention in the classroom. The provision of ergonomic, adjustable school furniture, in addition to ergonomic training and education on the importance of good posture, would better satisfy the spirit and meaning of the word prevention. The analysis of children's classroom environments, combined with training and education, is especially important in light of the increased use of video display terminals (VDTs) among children both at school and at home. Guidelines for proper VDT use are well documented for adults, however, they are not readily available for children. A unique and important opportunity exists to protect our schoolchildren from injury, as they are not only our youngest workers of today, but also our adult workers of tomorrow. The adult world of work with all of its ergonomic focus is not the proper entry point to begin to take responsibility for postural health.

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